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IDEAS

Noise Pollution Control using Internet of Things (IoT) solutions

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Abstract.

At present, noise is one of the main environmental pollutants that even government agencies are paying attention to find solutions for its control. Noise pollution traditional methods are based on expensive electronic de-vices—limited to constant monitoring in real-time. In recent years, (IoT), and the Internet of Things diverse strategies have been proposed to tackle this issue by offering low-cost sensors, capturing and storing real-time data for better decision-making processes. This article presents the results from an exploratory literature revision regarding Noise Pollution solution proposals based on IoT. in 17 articles indexed in a high-impact database with four research questions about the proposed layers, cover for the control of environmental noise, technological elements, and current limitations and gaps in the problem of environmental noise, defining an OiT system of four layers to define the functionalities of monitoring and analysis of noise lev-els, the review process established stages such as the identification of criti-cal terms, location of literature, evaluating and selecting literature, organiz-ing and finally summarizing the literature review..

Keywords: IoT, Noise, Pollution, Environment, Urban

Resumen. En la actualidad, el ruido es uno de los principales contaminantes ambientales al que incluso los organismos gubernamentales prestan atención para encontrar soluciones para su control. Los métodos tradicionales de control de la contaminación acústica se basan en costosos dispositivos electrónicos limitados a la monitorización constante en tiempo real. En los últimos años, (IoT), y el Internet de las Cosas diversas estrategias se han propuesto para hacer frente a este problema, ofreciendo sensores de bajo coste, la captura y almacenamiento de datos en tiempo real para una mejor toma de decisiones pro-cesos. Este artículo presenta los resultados de una revisión exploratoria de la literatura sobre propuestas de solución a la contaminación acústica basadas en IoT. En 17 artículos indexados en una base de datos de alto impacto con cuatro preguntas de investigación sobre las capas propuestas, cobertura para el control del ruido ambiental, elementos tecnológicos, y limitaciones y lagunas actuales en la problemática del ruido ambiental, definiendo un sistema OiT de cuatro capas para definir las funcionalidades de monitorización y análisis de los niveles de ruido, el proceso de revisión estableció etapas como la identificación de términos críticos, localización de la literatura, evaluación y selección de la literatura, organización y fi-nalmente resumen de la revisión de la literatura.

Palabras claves: IoT, Ruido, Contaminación, Medio Ambiente, Urbano

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Introducción

Noise pollution has become one of the most environmental pollutants in cities, get-ting more and more attention from government agencies each time [1]. This issue has significantly increased due to population growth and urban development among other factors [2]. Additionally, a 60% population increase is expected by the end of 2030, which will make us face even more noise pollution challenges for governments [3].

To control noise pollution, governments worldwide are considering establishing regulations and noise pollution management. [4] which generally follow guidelines for urban noise suggested by the WHO 1999. In this regard, Peru approved the Envi-ronmental Quality Plan (EQSP) and Maximum Permissible Limits (MPL) (LMP) for the 2021-2023 period [5].

On the other hand, noise control traditional methods in urban areas are mainly used by professionals who register and analyze noise data in places of interest using a port-able sonometer; however, this method is not an answer to constant measuring since measuring devices are costly apart from having significantly accurate noise maps [6]

Diverse strategies based on the Internet of Things (IoT) have been suggested in re-cent years, offering low-cost alternatives for constant monitoring with the possibility of data storage captured in real-time, helping in decision-making processing. [7] [6][8].

With the eventual aim of becoming familiarized with recent contributions, this ar-ticle presents the results of a based IoT literature exploratory revision for noise pollu-tion, also known as sound pollution or acoustic pollution. Such results provide updated information to the competent authorities so that pertinent actions are taken to benefit the citizens.

Additionally, the results of this revision may provide an initiative for its imple-mentation within the Digital Government Plan of the Metropolitan Municipality of Lima, which already has a Monitoring and Surveillance Sound Pollution Program within its action plan for its prevention in the Lima province (2021-2025)[9]

This document is organized in the following sections. After the introduction, basic concepts supporting this study are presented, methodology, results, and conclusions [9].

Basic concepts

Noise Pollution Control

Noise is defined by WHO as an unpleasant and annoying sound potentially harmful to hearing (WHO, 1999); undesirable annoying sounds harmful to people's mental health [9] composed by noise in the environment from different sources outside ven-ues or properties [9] noise emitted by automotive, train and air traffic, construction works and general outdoor noise (WHO, 1999).

In this document, authors assume that pollution noise control requires surveillance which is the set of actions leading to the evaluation and monitoring of noise pollu-tion levels to verify environmental regulations compliance and identify pollution sound sources to establish prevention and control measures.

Noise levels are noise limit values that should be controlled in order to protect human health. Such values are expressed in LAeqT—continuous equivalent sound pressure levels with A adjusted weighting factor so that only the most harmful for the human ear frequencies are preserved, measuring sound levels of pressure in decibels.[9]. Table 1 shows noise levels allowed in Peru.

Table 1.

Noise Environmental Quality National Standards

Implementation	Values in LAeqT	
	Daytime schedule	Night hours
Special protection area	50	40
Residential area	60	50
Commercial area	70	60
Industrial area	80	70

Source: SINIA https://sinia.minam.gob.pe/normas/estandares-calidad-ambiental

Sonometer is an instrument used for measuring sound pressure levels with domain weighting in the frequency and mean standardized exponential time-weighting accord-ing to IEC 61672 Standards –all its parts or substitute parts.[9].

The Internet of Things

IoT is an idea of connecting physical objects to the Internet, playing a notable role in improving the quality of a lot of domains [10], [11]. There is a special interest in the IoT application in the urban scope since it facilitates the adequate use of public re-sources, improving the quality of services to citizens and minimizing public admin-istration operative costs[12].

Diversity in IoT architecture diversity starts with the most basic of three tiers: Per-ception, Network, and Application. A layer of perception is physical in which envi-ronmental capturing data sensors are found. Next, the Network layer connects devices to servers within a network also used to transmit and process data. In contrast, the Application layer defines applications where IoT may be deployed, i.e., houses and intelligent cities [13].

In this work, the 4-layer architecture (Figure 1) is used by [14] to describe the func-tionalities of the IoT monitoring and noise level analysis system proposal. Layers: Capture, Storing, Analysis, and Visualization. The capture layer through a sensor device captures noise levels deployed in a device screen sent by a storing layer proto-col.

In the storage layer, data is captured through an asynchronous connection per-formed from the device direction and sending characteristic code so that as data is captured, it is categorized in line with noise levels ranked and stored in a non-relational database through an appropriate ID for each capture session.

In the visualization layer, categorized data are presented through a real-time graph-ic. At the same time is possible to perform an inquiry over stored data in each capture session. As per the analysis layer, it is possible to create unsupervised learning mod-els whose results are presented in the visualization layer.

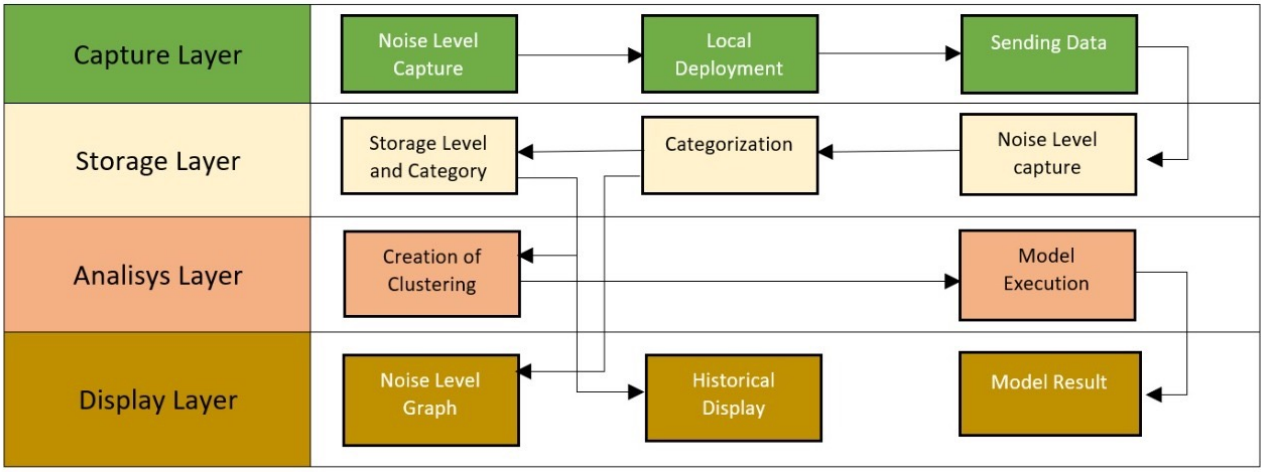

Figure 1. IoT System Layers

For data capturing, all IoT applications need to have one of more environmental data-gathering sensors. Sensors are essential components of intelligent objects. Simi-larly, one of the most important aspects of The Internet of Things is context aware-ness, which is impossible without sensor technology. Also, IoT is usually small, low-cost, low-energy consumption limited by battery capacity and deployment ease factors [13].

Research Methodology

- Literature exploratory revision may provide answers to the following:
- Q1: What are solution implementation proposals for noise pollution based on IoT noise con-trol?
- Q2: Which layers are covered in the planning of IoT-based noise pollution solutions?
- Q3: What technological elements have been used in planning IoT-based noise pollution solu-tions?
- Q4: What are the limitations or gaps in recent research regarding the study problems?

The revision process was performed under the following stages: (1) Identifying key terms, (2) locating topic literature, (3) literature evaluating and selection, (4) literature organizing (5) summarizing of literature revision [15].

- Key terms identified: “noise pollution,” “noise pollution,” “internet of things,” and IoT.
- For literature location, Google Scholar was used.
- Literature selection was based on the following criteria: Only journal articles and conferences, supporting only articles and articles published in the last six years. The revision or state-of-the-art articles were excluded resulting in 28 potential articles analyzed by content, excluding those without any envi-ronmental noise IoT contribution. A total of 18 articles for detailed reading were selected (Table 2).
- Finally, an analysis of each selected article is carried out

Table 2.

Selected articles

No.	Author (s)	Year	Title	Journal /Conference
1	Jakob Abeßer Robert Gr¨afe Christian K¨uhn, Tobias Clauß, Hanna Lukashevich	2018	A distributed sensor network for monitoring noise levels and noise sources in urban environments.[16]	IEEE 6th International Conference on Future Internet of Things and Cloud (FiCloud)
2	Abdulaziz Almehmadi	2018	Smart City Architecture for Noise Pollution Mitigation through the Internet of Things. [3]	IJCSNS International Journal of Computer Science and Network Security
3	Maja Anachkova, Simona Domazetovska, Zlatko Petreski, Viktor Gavriloski	2021	Design of low-cost wireless noise monitoring sensor unit. [6]	Journal of vibroengineering
4	Nureize Arbaiya, Syahir Ajwad Sapuana, Muhammad Shukri Che Laha, Mohamad Haris Haikal Othmana, Pei-Chun Linb	2019	The Construction Site Ambient Noise Monitoring System with the Internet of Things (IoT). [7]	Comput. Res. Prog. Appl. Sci. Eng. CRPASE
5	Jorge Granda Cantuña, Santiago Solorzano, Jean-Michel Clairand	2017	Noise Pollution Measurement System Using Wireless Sensor Network and BAN Sensors. [8]	Fourth International Conference on eDemocracy & eGovernment (ICEDEG)
6	Gabriel E. Chanchí Manuel A. Ospina Manuel Saba	2020	Sistema IoT para la monitorización y análisis de niveles de ruido. [14]	Espacios
7	D.A. Janeera, H. Poovizhi, S.S. Sheik Haseena, S. Nivetha	2021	Smart Embedded Framework using Arduino and IoT for Real-Time Noise and Air Pollution Monitoring and Alert system. [2]	Proceedings of the International Conference on Artificial Intelligence and Smart Systems (ICAIS-2021)
8	P. Maijala Z. Shuyang T. Heittola T. Virtanen	2018	Environmental noise monitoring using source classification in sensors. [17]	Applied Acoustics
9	Gonçalo Marques, Rui Parma	2020	A real-time noise monitoring system based on the Internet of Things for enhanced acoustic comfort and occupational health. [18]	IEEE Access

10	C. Peckens C. Porter T. Rink	2018	Wireless sensor networks for long-term monitoring of urban noise. [19]	Sensors
11	Harold Adrián Peña, Gabriel Elías Chanchí, Wilmar Yesid Campo	2020	Sistema IoT para la monitorización de niveles de ruido en zonas aledañas al aeropuerto de Cartagena de Indias. [20]	RISTI
12	M. Quintana-Suárez D. Sánchez-Rodríguez I. Alonso-González J. Alonso-Hernández	2017	A low-cost wireless acoustic sensor for ambient assisted living systems. [21]	Applied Sciences
13	Vladimir Risojevic, Robert Rozman, Ratko Pilipovic, Rok Cesnovar, Patricio Bulic	2018	Accurate indoor sound level measurement on a low-power and low-cost wireless sensor node. [22]	Sensors
14	J. Segura J. Pérez M. Cobos E. Navarro S. Felici A. Soriano F. Montes	2016	Spatial Statistical Analysis of Urban Noise Data from WASN Gathered by an IoT System: Application to a Small City. [23]	Applied Sciences
15	S. Soniya A. Sindhu G. Manasa D. Mohan	2020	IoT-Based Air and Noise Pollution Monitoring System in Urban and Rural Areas. [24]	International Journal of Research in Engineering, Science, and Management
16	Xueqi Zhang, Meng Zhao, Rencai Dong	2020	Time-Series Prediction of Environmental Noise for Urban IoT Based on Long Short-Term Memory Recurrent Neural Network. [1]	Applied Sciences
17	Qiuling Zheng	2017	Design and Application of Residential Area Noise Monitoring Based on Wireless Sensor. [25]	International Journal of Online Engineering

Source: Own research

Results

Proposals

Table 3 describes IoT proposals for environmental noise control, summarized in the following categories: Environmental Noise Monitoring Systems, Wireless sensor, and Deployment Optimization Algorithms.

Table 3

Environmental Noise Control Proposals

Proposals	Autor (s)	Objective
Environmental Noise Monitoring systems	[3][20][2]	Urban areas noise measuring
	[7][18][20][24]	Noise measurement in construction areas and interior areas near airports and vehicles
	[8][16][17][23][1]	Noise measurement—health effects, emission sources, Measurement and prediction— affected areas
Wireless Sensor	[21][22]	Noise measurement—Assisted Living Ambience (AAL)—Interior
	[6][19]	Urban areas noise measurement
Deployment Optimization Algorithm	[25]	N/A

Source: Own research

Suggested proposals by government organizations based on standard regulations: [16] StadtLarm—Germany standard research project; [19] Based on Board 49/2002 –European Union[23] also based on Board 49/2002—European Union and 37/2006 Spain Lawv[24] India regulations [1] Noise Environmental Pollution Prevention Law—China.

Covered Layers—IoT Proposals

In order to determine covered layers in IoT solutions, classified articles in the Envi-ronmental Noise Monitoring Systems category were considered. Table 4 details layers covered by IoT proposals for environmental noise control---summarized in the follow-ing layers: Capture, Storage, Analysis, and Visualization.

Table 4

Covered layers in IoT proposals for environmental noise

Layer	Author (s)
Capture	[16][3][14][2][7][18][20][24][8][17][23][1]
Storage	[8][16][23][1]
Analysis	[6][19]
Visualization	[16][3][7][14][2][17][18][20][1]

Source: Own research

Technological elements used in IoT proposals

In Table 5, the solution relation in IoT proposals for environmental noise control

Table 5.
Covered layers in IoT proposals for environmental noise

No.	Author (s)	Capturing	Storage	Analysis	Visualization
1	[16]	Raspberry Pi 3 (CM3) + 1 GB de RAM y 1,5 GB de flash MEMS microphone	Central Server	Classification Model - Hybrid Deep Neural Network	Web map using interactive map based on an open-source framework (https://mapbender3.org/)
2	[3]	SOC (System on Chip) uses Windows 10 IoT core, GPS Shield, Adafruit Ultimate GPS HAT for Raspberry Pi with an antenna, a sound sensor Microphone amplifier Adafruit Electret - MAX4466 adjustable gain and GSM module	Three servers: (1) Storage server, (2) analytical server, and (3) web server	Support Vector Machine Support classifiers (SVM) y Random Forest	Portal Visualization Web Interface
3	[7]	Raspberry Pi 3 B+ 8gb memory Raspbian.OS	window remote desktop MySQL		Information Summary Interface noise data analysis Interfaz management—data registry Data Report
4	[8]	Arduino Pro Mini. Main board: Proteus software .	GUI Visual Studio, C# y SQL. 3-Layer architecture **(No IoT)**		
5	[14]	Commercial Sonometer UT353BT	Framework jsondb -non-relational database	Vector support Classifiers Machine (SVM) y K-Means	Web visualization Interface (portal)
6	[2]	Arduino Uno processor is used in the proposed noise and air pollution monitoring system with IoT. Port 9600 is used for providing a 5V DC power supply to the Arduino board.	Data is gathered from entirely different devices that serve to transmit to an online server mechanically.		Pollution reduction over a 12-month period

7	[17]	Raspberry Pi Foundation the audio codec 24 bits Microphone	a single purpose and interest. Further, this information is		Visualization Web Interface (portal)
8	[18]	iSoundMobile, Sensor POW-1644P-B-R, Micro-controller FRDM-KL25Z y Rasberry PI	SQL SERVER database using web services		Portal Web using ASP.NET C#. Data consulting: graphical and numerical
9	[20]	ESP-32 Card Sensor reading Noise level conversion	Python Framework Flask non-relational database	Supervised learning (clustering), Statistics production	Level noise-real-time visualization Data visualization by section Model Results
10	[23]	The used nodes in the network are based on Raspberry Pi B (RPi) platform. This platform is based on Broadcom BCM2835 System-on-Chip (SoC)	Using previously digital recorded audio files of road traffic in one of the locations, the mean and standard deviation of the LeqA,10s during a 10 min period Have analyzed.		The 78 locations are divided into two sets in order to check the validity of the proposed models: A modeling set, composed of 68 locations and a validation set has 10 locations.
11	[24]	MQ 135 Noise sensor LM393 Arduino UNO RFID GSM/GPRS	Android application SMS Cloud Message service		Sampling valid through a LED through card
12	[1]	Level sound measure HS5633TW IP-Link2220H Zigbee wireless protocol.	Local server	Red Deep Learning LSTM	Local Web system network

Source: Own research

Conclusions

This research has reviewed a proposal for IoT-based technology solutions for envi-ronmental noise control, categorizing environmental noise monitoring system solu-tions, wireless sensors, and deployment optimization. Additionally, environmental noise monitoring systems solutions were considered to determine covered layers and elements used in IoT systems solutions.

Search results let countries like China become known for planning solutions gener-ated from government regulations such as the Noise Environmental Pollution Preven-tion Law.

A significant limitation in these kinds of work is the IoT solution approach, in-cluding citizen awareness of environmental noise control.

Future work

Considering the Digital Government Plan from the Metropolitan Municipality of Lima—Sound Pollution Monitoring and Surveillance Program (OVMCS) within their Action Plan for the prevention and control of sound pollution in the Lima prov-ince 2021-2025 (Lima Municipality, 2021), it is necessary to approach an IoT for environmental noise purposes that includes a feature allowing citizens to measure levels of environmental noise through a mobile device from a certain location.

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