Implementation of Intelligent Transportation System using Smartphone Sensors to Improve Traffic Conditions

Chai Ying Chian
School of Technology
Asia Pacific University of Technology and Innovation (APU)
Kuala Lumpur, Malaysia
tp056025@mail.apu.edu.my

Dr. Intan Farahana Binti Kamsin
School of Technology
Asia Pacific University of Technology and Innovation (APU)
Kuala Lumpur, Malaysia
intan.farahana@staffemail.apu.edu.my

***Abstract*— The research stated some environmental and health issues that are caused by excess exhaust emissions from road vehicles. Therefore, efforts to address these issues by implementing an intelligent transportation system to manage the traffic conditions. The proposed system is designed to run on smartphone by leveraging the smartphone sensors. It can detect and report current and upcoming road conditions, then manage those vehicles that enabled navigation services to non-busy roads. Probability sampling is performed to select participants for surveys in order to ensure the proposed system is reliable and meaningful to its users. The proposed system is varied to previous systems that it has no infrastructure installation and is able to work autonomously. It is a smartphone-based application system that can ease a lot of works to people. It has high mobility and need no physical maintenance.**

Keywords*— Intelligent transportation system, Smartphone sensors, Traffic conditions, Smartphone-based system

I. INTRODUCTION

Most vehicles waste time on the road and burn more fuel due to poor traffic conditions. As a result, excess exhaust gases are discharged, affecting air quality and environmental situation, as well as human health (A. Thakur & R. Malekian, 2019). In order to confront these problems, an intelligent transportation system is proposed to improve and optimize the situation. Smartphones as a common everyday necessity for modern people, are equipped with various embedded sensors which can be utilized in the proposed system. These microelectromechanical sensors with enhanced precision can support the operation and performance of the proposed system (Chiang, K.-W., Le, D. T., Duong, T. T., & Sun, R., 2020).

The implementation of the proposed intelligent transportation system is practical and contributive to address the issues raised. The application of the proposed system would help improve traffic conditions by automatically identifying current traffic flow and reporting to the system. Besides, it can predict traffic conditions and appropriately distribute vehicles to alternative routes. Therefore, road congestion is avoided and the volume of vehicles on roads is managed and monitored to ensure smooth traffic. As a result, the time that vehicles spend on roads to arrive destinations is reduced and becomes manageable. Not only that, but all processes also require no manual intervention from users. The proposed system can work autonomously entirely depending on the operation of the sensors.

Remainder of this research is organized in the following order. In Section 2, involved domains and comparison of similar systems are illustrated. From Section 3 until Section 6, problem statement, research aim, objectives and questions are stated. In Section 7, research significance is justified to show the value of this research. The methodology for the research is discussed in Section 8 before outlining the proposed system in Section 9. Conclusion of the research and the proposed system are highlighted with relevant significances in Section 10.

II. LITERATURE REVIEW

A. Smartphone Sensors

The presence of smartphone sensors is one of the critical elements that makes smartphones somewhat more robust than a computer in some extent. Traffic management around the world is able to be applied and implemented through the help of smartphones (Astarita, V., Festa, D. C., & Giofrè, V. P., 2018). This is due to the availability of numerous sensors embedded in smartphones. This allows the implementation of intelligent transportation system with smartphones become practical and persuasive. This is because these in-built smartphone sensors are capable of identifying distinct patterns and situations during real-life driving experience (Kashevnik, A., Lashkov, I., Ponomarev, A., Teslya, N., & Gurtov, A., 2020). Some of the smartphone sensors that are essential for the intelligent transportation system are accelerometers, gyroscope, magnetometer, GNSS and camera. The first three sensors assist to detect and recognized any predictable and existing traffic anomalies, and then locations are identified uses GNSS (Krichen M. , 2021). These sensors usually collaborate to be used for calculation and evaluation of one-dimensional movement, rotation, velocity, orientation and location of an object (Sumeer S & Malathy C, 2022). Rather than planning costly sensors deployment in various vehicles and different corners or junctions of the roads, the existing technology of smartphones is sufficient to accomplish the research aim for the implementation of intelligent transportation system to manage the traffic. Therefore, smartphone sensors are adequate for evaluation and calculations such as deflection angle, velocity, position, acceleration and deceleration to support the system functionality (Krichen M. , 2021).

1) Motion Sensors

Motion sensors can monitor and measure the forms of a device's motion, orientation, acceleration and etc. (Sattar, S., Li & Chapman, M., 2018). The device's location and movement can also be spotted with the present of the sensors. Some of these sensors are accelerometer and gyroscope.

Accelerometer is capable of sensing and measuring the tilt, vibration or acceleration of an object which is in motion (Kumar, K., Sharma, A. & Tripathi, S., 2021). As such, the sensor will capture signal and data after tracking the motion and acceleration patterns of the vehicle. It can evaluate vehicle orientation and detect the real-time driving speed accurately by calculating the smartphone's linear speed (Krichen M. , 2021). These abilities make accelerometer one of the most important sensors for smartphone-based intelligent transportation system.

Gyroscope supports the function of accelerometer in a combination to improve data accuracy. It gives directional and orientational information more accurately when detecting positions like up-down, left-right, as well as calculates the dimensional rotation of an object body (Krichen M. , 2021). In other words, it tells the accelerometer of the precise orientation of the smartphone's screen and helps to sense tilting or position steering. It plays a vital role in the implementation of intelligent transport system to detect and estimate the upcoming traffic conditions.

2) Position Sensors

Position sensors are used to display the physical location of the device in a local-level coordinate system (Sattar, S., Li & Chapman, M., 2018). For example, magnetometer and GNSS receiver.

Magnetometer sensor is used in conjunction with the accelerometer and gyroscope sensors to validate the exact spot of the smartphone in a physical area. It is capable of detecting magnetic fields and alter the smartphone's voltage output to show the north way, which is a compass (Krichen M. , 2021). The sensor does not operate as single unit for its functionality, it relies on the data collected from the accelerometer sensor and GNSS in the smartphone. Thus, it is used to describe a particular direction or location in the intelligent transportation system.

The Global Navigation Satellite System, or GNSS receiver is necessary for smartphones, and the Global Positioning System (GPS) is inclusive in the receiver. Smartphones are built-in with GNSS receiver for location delivery to the server (Astarita, V., Festa, D. C., & Giofrè, V. P., 2018). It is important for traffic situation supervision because it navigates the most recommended route to avoid any special conditions on the road. Besides, it reveals and shares traffic conditions for different route options toward certain destinations (Dabove, P., Di Pietra, V., & Piras, M., 2020).

3) Camera Sensors

The type and quality of a smartphone affect the resolution levels of images and videos that are captured and recorded by the camera sensor (Krichen M. , 2021). It can assist to identify the traffic pattern and distinguish the current traffic state.

B. Smartphone-based Intelligent Transportation System

Smartphone-based sensing application systems have recently become common as more sensors are embedded in smartphones (Sattar, S., Li & Chapman, M., 2018). Smartphone-based intelligent transportation system is expected to deliver a situational assessment system using a variety of in-built smartphone sensors and make rapid decisions based on data collected from the smartphone sensors to improve traffic conditions (Guerrero-Ibáñez, J., Zeadally, S., & Contreras-Castillo, J., 2018). Therefore, it is imperative for the system to constantly analyze and give accurate and efficient traffic condition prediction, and detailed and exact traffic status information (A. Boukerche & J. Wang, 2020). In addition, the proposed intelligent transportation system is supposed to address the environmental and human health issues caused by long-hour of exhaust gases emission from motor vehicles due to poor traffic conditions. It is mandatory for the proposed system to satisfy some fundamental requirements, which are:

i. Provide the best destination route with the smoothest path

ii. Predict the volume of vehicles on certain roads

iii. Maintain the number of vehicles at certain level

The intelligent transportation system is used to improve the traffic conditions and to effectively maintain smooth travels, also a healthy environment. The intelligent transportation system proposed in this research depends on smartphone sensors for its proper operation and necessary traffic conditions assessment.

III. SIMILAR SYSTEM

A. Vehicle Clustering – VANET

Vehicle clustering consists of cluster heads, which will collect real-time data from cluster members for traffic control center to perform data processing (Rui et al., 2018).

Vehicular Ad-hoc Network (VANET) is a wireless communication network evolved from Mobile Ad-hoc Network (MANET) used for monitoring traffic conditions especially road congestion (Upadhya, A., & Gajjar, A., 2020). It allows vehicles on the road to communicate with each other to share and exchange the traffic information in order to detect and track road congestion (Mohanty, A., Mahapatra, S. & Bhanja, U., 2019). It is used to broadcast the accumulated information between devices or vehicles and the system (Cherkaoui, B. et al., 2019). All involved devices can act as either routers, sensors or receivers (Mohanty, A., Mahapatra, S. & Bhanja, U., 2019). It consists of three categories of communications, which are inter-vehicle communication, vehicle-to-roadside communication and inter-roadside communication (Rui et al., 2018).

Fig. 1. VANET for traffic congestion (Amjid, A., Khan, A., & Shah, M. A., 2020)

B. Acoustic Sensing – DAS

Acoustic sensing is one of the infrastructure-less technique used to monitor traffic conditions. (Kaur, A., Sood, N., Aggarwal, N., Vij, D., & Sachdeva, B., 2017). The

advantage is to save the expensive installation and maintenance costs. It typically utilizes sensors like microphones to collect accumulated acoustic signals (Vij, D., & Aggarwal, N., 2018).

Distributed optical fiber acoustic sensing (DAS) is a technology that can detect traffic flow by identifying traffic vibration signals (Liu, H., Ma, J., Yan, W., Liu, W., Zhang, X., & Li, C., 2018). Approaches for high-quality signal processing algorithms need to be developed for the mechanism in order to accurately analyze the compiled data (Angayarkanni, S. A., Sivakumar, R., & Rao, Y. R., 2019). It has to distinguish and classify several types of noise that can be found on the road in traffic with techniques like threshold-based classification, Neural Network and frame-wise classification, etc. (Kaur, A., Sood, N., Aggarwal, N., Vij, D., & Sachdeva, B., 2017).

Fig. 2. DAS System (Liu, H., Ma, J., Yan, W., Liu, W., Zhang, X., & Li, C., 2018)

C. Compare & Contrast Table

TABLE I. VANET AND DAS FEATURES COMPARISON TABLE

System / Features	VANET	DAS
Algorithm	Fuzzy *K*-means clustering, Crowdsourcing	Improved wavelet threshold, Improved dual-threshold
Structure	Distributive	Distributive
Physical components	Devices incorporated into vehicles	Fiber optic cable
System establishment (Sensor installation)	Integration of roadside and vehicle	Roadside
Components maintenance	/	/
Cost	High	Low
Sustainability	High	High
Track vehicle speed	/	/
Track congestion	/	/
Predict upcoming traffic	/	
Capture live traffic image		
Live traffic broadcast	/	
Traffic control		
Mobile application		

IV. PROBLEM STATEMENT

Study shows that Malaysians prefer to bring their own transport and are less interested in the public transport system (S N Brohi, T R Pillai, D Ludlow & J Bushell, 2018). The increase in number of vehicles is one of the causes for road congestion, as road capacity is exhausted, and vehicles speed is slowed down (Koźlak, A. & Wach, D., 2018). In addition, gaseous emissions from various motor vehicles over long periods of time can deteriorate existing air pollution and urban air quality problems, thereby worsening the environment and human health (Li, 2020). These issues are affecting citizens' respiratory health (Nur Faseeha Suhaimi, Juliana Jalaludin & Muhammad Afif Mohd Juhari, 2022). The high volume of road vehicles can be supervised by accommodating vehicles with smart devices capable of spotting the traffic conditions and proposing alternative routes (Kumar, S., Tiwari, P. & Zymbler, M., 2019). Smartphone sensors are convenient and accessible to fulfill the mentioned requirements and detect road conditions (Chugh, G., Bansal, D. & Sofat, S., 2014).

V. RESEARCH AIMS

The main aim of this research is to improve traffic conditions by implementing intelligent transportation system with smartphone sensors in order to reduce the environmental and human health concerns caused by the excessive emission of harmful exhaust gas from vehicles.

VI. RESEARCH OBJECTIVES

1) To implement intelligent transportation system utilizing smartphone sensors.
2) To detect potential road conditions through the intelligent transportation system.
3) To report detected road conditions on the system automatically.
4) To control the volume of vehicles on roads through the intelligent transportation system.

VII. RESEARCH QUESTIONS

1) How to implement intelligent transportation system that relies on smartphone sensors?
2) How does the intelligent transportation system detect potential road conditions?
3) How can the detected road conditions be automatically reported to the system?
4) How does the intelligent transportation system control the volume of vehicles on road?

VIII. RESEARCH SIGNIFICANCE

The findings of this research contribute to society, traffic management and road users, as well as researchers who want to enhance relevant systems in the future. The proposed system is user-friendly, which can be easily downloaded and installed on smartphones. It is highly portable and helps save road users time and cost. Beyond that, traffic remains smooth when vehicles do not waste additional time on roads. Therefore, exhaust emissions are reduced, environmental

pollution is also controlled, and related human health concerns can be addressed.

This research highlights how smartphone-based application system can save on traditional infrastructure construction and maintenance costs, also shows the ease of taking advantage of available advanced technology. Some future studies regarding to transportation management can becarried out referring to this research for continuous development of potential systems to address more issues.

IX. METHODOLOGY

A. Sampling Method

This research uses systematic sampling for data collection, as the proposed system will consist of a large number of users. The sampling method ensures that the chosen participants are evenly distributed in the population. Therefore, the sample can be said to be representative, and thus, the result produced is reliable and unbiased.

With this method, the population is assigned a unique symbol, where there will be three distinct symbols for allocation within the participants. Participants with the selected symbol are split into the sample and sample units are involved in the survey later.

B. Identify Respondents

The respondents to the survey are licensed drivers, vehicle owners and smartphone users. This is because the proposed system is designed for vehicle while moving on the road to regulate traffic conditions. Besides, it is a smartphone-based application system. Any road users who have the system installed in their smartphones are able to run the system and contribute to the data collection, data calculation and traffic management. The sample size is 150 respondents to ensure that the data compiled from these respondents is adequate and qualified to make inferences on behalf of the perceptions of the proposed system users.

C. Data Gathering Methods

Survey is used as data gathering method in this research to find out the required information from target users by distributing the set of similar questions to the sample. Various channels online can be used to get in touch with all respondents, such as social media and e-mail. It saves time to gather required data from large group of people.

The questions in the survey comprise of open and closed questions. There will be five multiple choice questions, three rating questions, as well as one objective and one subjective open questions.

In order to ensure the validity and reliability of the survey, the questions are passed to expert for validation beforehand so that consistent results are produced. Then, a pre-test will be done to get feedback for amendment on the survey questions before conducting the pilot test.

The returned survey feedback is used to perform analysis to study the functional compatibility of the proposed system for general public usage. It also helps assess the viability of the system for widespread practice in the country.

X. OVERVIEW OF THE PROPOSED SYSTEM

Figure 3 indicates the concept of the overall operation of the proposed intelligent transportation system. First, traffic conditions are captured by smartphone sensors. Then, corresponding schemes or system actions are proposed for the identified traffic conditions. The procedure is capturing and uploading data, then processing the data and generating designed schemes to handle the reported situation.

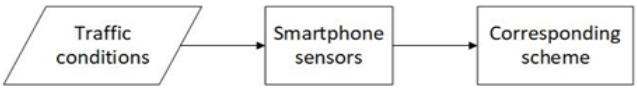

Fig. 3. Overview of Proposed System Operation

Figure 4 is a flow chart that illustrates the system flow of the proposed intelligent transportation system. The system will ensure it is able to run on the device before acquiring the position of user. The operation proceeds by identifying whether the user needs navigation services. Then, the system will gather data from all the required smartphone sensors.

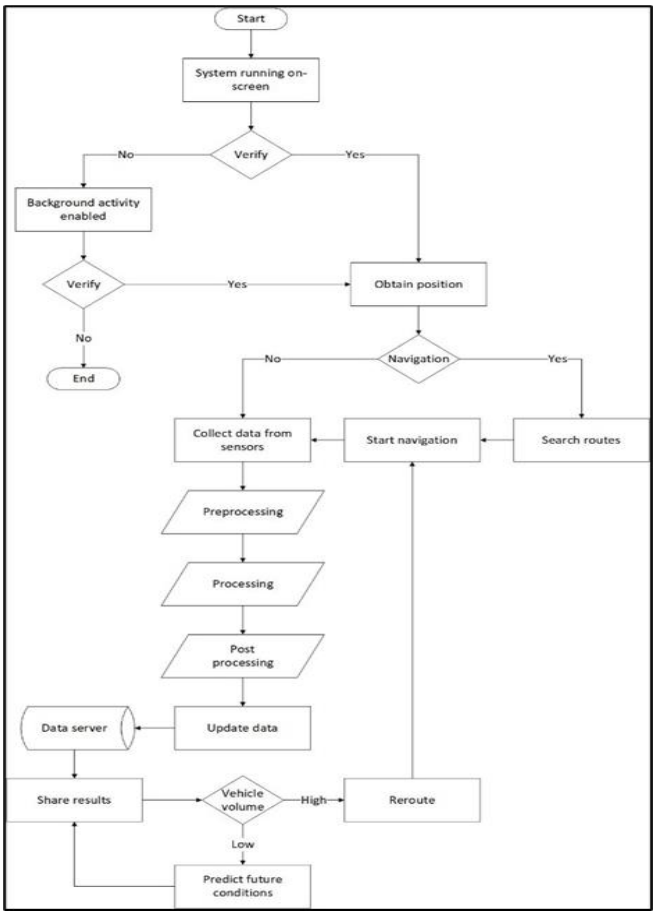

Fig. 4. Proposed Intelligent Transportation System Flow Chart

This data will go through multiple processes before being updated and shared. In preprocessing stage, the raw data collected is filtered and converted into organized datasets. The data is also reoriented from device coordinate system values into local-level coordinate system values to avoid possible issues triggered by smartphone positioning arrangement (Sattar, S., Li & Chapman, M., 2018). In processing stage, datasets from previous stage are further processed using approaches like threshold-based approach and machine learning. In post processing stage, the data is being integrated with crowdsourcing sources for higher precision and reliability while reporting and predicting traffic

conditions. It is crucial to keep generating exact and latest data because the results might affect the navigation services.

Users with navigation services will be automatically rerouted if heavy traffic is detected ahead. Instead, the system will continuously detect the traffic conditions to prevent high volume of vehicles from being diverted to busy traffic.

XI. CONCLUSION

The proposed system is a smartphone-based intelligent transportation system that provides navigation services and traffic management. It relies on the operation of smartphone sensors and thus does not require surplus cost and time to install infrastructure on roads or additional devices for vehicles. This also avoids the necessity for maintenance of hardware components. The system runs on a smartphone also does not require any embedded systems to be connected to vehicles, which will bring conveniences to people (Pezeira, S. et al., 2022). It also automates mostly work without user interference. Meanwhile, the environmental and human health issues are tackled as the main issue of excessive exhaust gas emission is reduced. The research also contributes to the development of similar systems in the future to enhance functionality and address more problems for people benefits.

REFERENCES

A. Boukerche & J. Wang. (2020). Machine Learning-based traffic prediction models for Intelligent Transportation Systems. Computer Networks, 21.

A. Thakur & R. Malekian. (2019). Fog Computing for Detecting Vehicular Congestion, an Internet of Vehicles Based Approach: A Review. IEEE Intelligent Transportation Systems Magazine, 8-16.

Amjid, A., Khan, A., & Shah, M. A. (2020). ANET-based volunteer computing (VBVC): A computational paradigm for future autonomous vehicles. IEEE Access, 71763-71774.

Angayarkanni, S. A., Sivakumar, R., & Rao, Y. R. (2019). A review on traffic congestion detection methodologies and tools. International Journal of advanced Science and Technology, 1400-1414.

Astarita, V., Festa, D. C., & Giofrè, V. P. (2018). Mobile Systems applied to Traffic Management and Safety: a state of the art. The First International Workshop on Mobile Systems applied to Traffic Management and Safety, Smart Vehicles and Smart Roads (MOBITraffic 2018), 407-414.

Cherkaoui, B. et al. (2019). Road traffic congestion detection in VANET networks. International Workshop on Web Search and Data Mining (WSDM), 1158-1163.

Chiang, K.-W., Le, D. T., Duong, T. T., & Sun, R. (2020). Chiang, K.-W., Le, D. T., Duong, T. T., & Sun, R. Remote Sensing, 19.

Chugh, G., Bansal, D. & Sofat, S. (2014). Road Condition Detection Using Smartphone Sensors: A Survey. International Journal of Electronic and Electrical Engineering, 595-602.

Dabove, P., Di Pietra, V., & Piras, M. (2020). GNSS Positioning Using Mobile Devices with the Android Operating System. International Journal of Geo-Information, 13.

Guerrero-Ibáñez, J., Zeadally, S., & Contreras-Castillo, J. (2018). Sensor Technologies for Intelligent Transportation Systems. Sensors, 24.

Kashevnik, A., Lashkov, I., Ponomarev, A., Teslya, N., & Gurtov, A. (2020). Cloud-Based Driver Monitoring System Using Smartphone. IEEE SENSORS JOURNAL, 14.

Kaur, A., Sood, N., Aggarwal, N., Vij, D., & Sachdeva, B. (2017). Traffic state detection using smartphone based acoustic sensing. Journal of Intelligent & Fuzzy Systems, 32(4), 3159–3166. doi:10.3233/jifs-169259 .

Kaur, A., Sood, N., Aggarwal, N., Vij, D., & Sachdeva, B. (2017). Traffic state detection using smartphone based acoustic sensing. Journal of Intelligent & Fuzzy Systems, 32(4), 3159–3166. doi:10.3233/jifs-169259 , 3159-3166.

Koźlak, A. & Wach, D. (2018). Causes of traffic congestion in urban areas. Case. SHS Web of Conferences, 9.

Krichen, M. (2021). Anomalies Detection Through Smartphone Sensors: A Review. IEEE SENSORS JOURNAL, 7207-7217.

Kumar, K., Sharma, A. & Tripathi, S. (2021). Chapter 9 - Sensors and their application. Electronic Devices, Circuits, and Systems for Biomedical Applications, 177-195.

Kumar, S., Tiwari, P. & Zymbler, M. (2019). Internet of Things is a revolutionary. Journal of Big Data, 21.

Liu, H., Ma, J., Yan, W., Liu, W., Zhang, X., & Li, C. (2018). Liu, H., Ma, J., Yan, W., Liu, W., Zhang, X., & Li, C. IEEE Access, 12.

LiWen-Whai. (2020). Chapter 2 - Air pollution, air quality, vehicle emissions, and environmental regulations. Traffic-Related Air Pollution, 23-49.

M.Y. Alam, A. Nandi, A. Kumar et al. (2019). Crowdsourcing from the True. Pervasive and Mobile Computing, 35.

Mehta, H., Kanani, P. & Lande, P. (2019). Google Maps. International Journal of Computer Applications, 41-46.

Mohanty, A., Mahapatra, S. & Bhanja, U. (2019). Traffic congestion detection in a city using clustering techniques in VANETs. Indonesian Journal of Electrical Engineering and Computer Science, 884-891.

Nur Faseeha Suhaimi, Juliana Jalaludin & Muhammad Afif Mohd Juhari. (2022). The impact of traffic-related air pollution on lung function status and respiratory symptoms among children in Klang Valley, Malaysia. International Journal of Environmental Health Research, 535-546.

Pezeira, S. et al. (2022). Smartphones and Integrated Control System for Hazardous Materials Transportation. 8.

Rui et al. (2018). A New Traffic Congestion Detection and Quantification Method Based on Comprehensive Fuzzy Assessment in VANET. KSII TRANSACTIONS ON INTERNET AND INFORMATION SYSTEMS, 41-60.

S N Brohi, T R Pillai, D Ludlow & J Bushell. (2018). Towards Smart Cities Development: A Study of Public Transport System and Traffic-related Air Pollutants in Malaysia. IOP Conference Series: Earth and Environmental Science, 10.

Sattar, S., Li & Chapman, M. (2018). Road Surface Monitoring Using Smartphone Sensors:. Sensors, 21.

Sumeer S & Malathy C. (2022). A Review on Road Condition Monitoring Using Smart Phones. GRADIVA REVIEW JOURNAL, 1574-1580.

Trapsilawatia, F., Wijayanto, T. & Jourdy, E. (2019). Human-computer trust in navigation systems: Google maps vs Waze. Communications in Science and Technology, 38-43.

Upadhya, A., & Gajjar, A. (2020). TRAFFIC CONGESTION DETECTION IN VANET. Tattva: An International Multidisciplinary e-Journal, 8.

Vij, D., & Aggarwal, N. (2018). Smartphone based traffic state detection using acoustic analysis and crowdsourcing. Applied Acoustics, 138, 80–91. doi:10.1016/j.apacoust.2018.03.029 , 80-91.