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Research on Multi-Dimensional Logistics Based on the Internet of Things

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Abstract: In this paper, we prompt a new multi-dimensional logistics method based on the Internet of Things (IOT). IOT is a good enabling technology for logistics and supply chains which implements seamless, real-time tracking and monitoring goods at the level of items. In this paper, we propose a solution, which adopts RFID/GPS/3G/GIS technologies to implement real-time surveillance of logistics in transit. Based on the proposed solution, we chose the tobacco logistics as an example and developed an actual monitoring system for Logistics & Distribution Center of China, which successfully implements real-time vehicle tracking and cigarette packages monitoring. The outcome indicates that this solution minimizes missing goods and effectively reduces wrong delivery.

1. INTRODUCTION

Internet of things (IOT), an application of the next generation Internet, has received much attention and will be a worldwide competition emphasis because IOT can not only realize the interconnection between things and things, but also between things and people. IOT will improve old industries and promote new ones. The popularization and application of IOT will not only influence the progress of industrialization and informationization [1, 2], but also have far-reaching impact on social economy and human life. The construction of modern logistics service system should be sped up to correspond with the development of informationization. Modern logistics should be the new force to promote the development of modern services as it has quicker reaction, integrated function, serialization service, normalized work, systematic target, modern method, networked organization, marketing organization and electronica information. It is of great theoretical value and realistic meaning to study the multi-dimensional synergy of logistic management in IOT environment.

In recent years, competition among enterprises gradually evolved into the races between supply chains, the logistics operation presents an appearance of personalized service increasingly due to the changing market demand. Logistics is defined as part of the supply chain process by American Logistics Management Association, which not only incorporates logistics into a collaborative management category between enterprises, but also requires enterprises consider their own logistics operation in a broader area. In addition, as management and information technology are crucial for the winning of enterprise group's competitive strength, the informatization construction of collaborative logistics management is particularly important.

As an emerging information technology, IOT could achieve interactive information sharing and real-time monitoring of things, which is popular with enterprises. If IOT could be successfully applied to the construction of tobacco collaborate logistics platform, it will provide the most effective techniques and methods to solve the problems existing in the current tobacco logistics platform.

A service description model of IOT based on WSDL is proposed and the core services in tobacco logistics are completely described by this model. Firstly, in view of the actual characteristics of IOT services description, the services contents that needed to be extended based on the traditional description model of web service named WSDL are analyzed, including the expansion based on the description objects and contents. Furthermore the expansion level and concrete structure of this model are given, and the physical objects of the service have been extended by the description of the role and its attributes involved in the IOT services, and the description contents of service have also been extended by the description of service acquisition method, service running prerequisite, service inputs and outputs, sub procedure and its flow in service, service sustaining and so on. Then the implementation of this model is discussed, choosing OWL for the formal description of this model, and the detailed description of the core services in tobacco logistics is completed by this proposed model.

The IOT is made up of three layers, perception layer, network layer and application layer. It is an intelligent network system that can distinguish, locate, track, monitor and manage things intelligently based on agreed agreement by using infrared sensing equipment, global positioning system, laser scanner and other sensors and RFID (radio frequency identification) technique and video identification technology. Man and things can communicate intelligently through IOT. It is a collective application and improvement of modern information technology using modern Internet technology, artificial intelligence technology, automotive technology and

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perceptive technology syndicated. IOT can be used into intelligent logistics widely which consists of three technology systems, perceptive technology, communication, network technology and intelligence technology.

Intelligent logistics can bring maximum profit to supplier and best service to customer with least natural and social resources by using information collection, dispose, circulation and management technology during the course of things transportation from supplier to customer. It is an integral logistics management system that can protect ecological environment furthest.

Intelligent logistics analyzes logistics system data by using data mining, artificial intelligence, decision theory, knowledge management and other relevant technology. It can support daily decision making and strategic policy of logistics system. So it has these characteristics, to acquire data diversely, to transport reliably with the support of Internet, to make decision, and manage intelligently with the help of abundant information.

2. THE BACKGROUND AND FRAME WORK OF LOGISTICS COLLABRATE ALGORITHM

With the development of information technology, such as information storage, information transmission and Internet, the security of information transmission has been heightened. As a main method of protecting image information, image encryption has made great strides in recent years. Chaos, the theory of relativity and quantum mechanics, are listed as the 20th century's greatest discoveries. It possesses the sensitive dependence on initial conditions and control parameters, pseudo random orbits and topological transitivity. These inherent properties can be well applied in the image encryption. So a large number of image encryption algorithms based on chaotic theory have emerged since the end of last century, and many exciting results are obtained. However, with the deep research and progress of information technology, the algorithms of image encryption which were once considered a strong safety and high efficiency, are now proved to be unsafe, of low efficiency and even unusable algorithms. How to base on the latest research results and to design a chaotic encryption algorithm for digital imaging with high efficiency and security by thorough analysis is becoming a problem that should be solved urgently.

The detected impulses will be removed by R algorithm. Let $f'_{i,j}$ be the value of the sample at statistics location (i,j). For the corrupted statistics (i, j), the sample size $(2L_f +1) \times (2L_f +1)$ is used. Starting with $L_f =1$, this sample size iteratively extends outward by one statistics in its four sides until the number of free statistics (denoted by $P_{i,j}$) within this sample size is not less than 1. Let $W'_{i,j}$ denote the values of free statistics in the concerned area, *i.e.*,

$$W'_{i,j} = \{f'_{i+s,j+t} \mid b_{i+s,j+t} = 0, b_{i,j} = 1,$$
$$(s,t) \neq (0,0), -L_f \leq s,t \leq L_f\} \tag{1}$$

The weighted mean value $g_{i,j}$ of the statistics values in $W'_{i,j}$ is defined as:

$$g_{i,j} = \frac{\sum_{f'_{i+s,j+t} \in W'_{i,j}} w_{i+s,j+t} f'_{i+s,j+t}}{\sum_{f'_{i+s,j+t} \in W'_{i,j}} w_{i+s,j+t}} \tag{2}$$

where $w_{i+s,j+t}$ means the weight of $f'_{i+s,j+t}$. Let $m'_{i,j}$ be the median value of $W'_{i,j}$. Because the median value has the least probability to be the value of the corrupted statistics [3-4], $m'_{i,j}$ is utilized to determine $w_{i+s,j+t}$. It is easy to understand that the smaller the absolute difference between $f'_{i+s,j+t}$ and $m'_{i,j}$, the larger the weight $w_{i+s,j+t}$ should be to strengthen the influence of $f'_{i+s,j+t}$ on $g_{i,j}$. Based on extensive simulations which indicates that $w_{i+s,j+t}$ is dependent on both the above absolute difference and noise ratio, $w_{i+s,j+t}$ is chosen as:

$$w_{i+s,j+t} = R + (1-R) \sqrt{\frac{\frac{|f'_{i+s,j+t} - m'_{i,j}|}{f'_{max} - f'_{min}}}{1 - \frac{|f'_{i+s,j+t} - m'_{i,j}|}{f'_{max} - f'_{min}}}} \tag{3}$$

Where f'_{max} and f'_{min} denote the maximum statistics value and the minimum one in the concerned area, respectively.

The output is obtained by:

$$h_{i,j} = b_{i,j} \cdot g_{i,j} + (1 - b_{i,j}) f'_{i,j} + \Delta\omega_{i,j} \tag{4}$$

Then we have:

$$q_i = \left[x, y, z, \psi, \theta, \phi\right]_i^T \quad, \quad q = \left[q_1^T, q_2^T, ..., q_n^T\right]^T \tag{5}$$

The equation is established. The R weighted mean algorithm takes the Cartesian coordinates and Euler angle that respectively shows the position and direction of sample orient as the generalized coordinate, and establishes statistics equation by R weighted mean algorithm:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}}\right)^T - \left(\frac{\partial T}{\partial q}\right)^T + \phi_q^T \rho + \theta_q^T \mu = Q \tag{6}$$

Integrity Constraint Equation:

$$\phi(q,t) = 0 \tag{7}$$

Non-Integrity Constraint Equation:

$$\theta\left(\dot{q}, q, t\right) = 0 \tag{8}$$

3. APPLICATION OF IOT TECHNOLOGY IN THE INTELLIGENT LOGISTICS FIELD

The development of intelligent logistics needs to use perception technology widely because the job objects of logistics are things, which have all kinds of varieties and are always in the process of transport and exchange. RFID technology and bar code automatic identification technology are always used to distinguish, track things. RFID technology, laser, infrared technology and bar code technology are always used to sort, select and count things. GPS (global position system), GIS (geography information system), RFID and on-board video technology are always used to locate and trace things. Video identification, RFID and GPS are always used to monitor things. Sensor technology, RFID and GPS are always used to percept and identify special things.

So these perception technologies are always used in intelligent logistics field, RFID, GPS, sensor technology, video identification and monitor technology, laser, infrared technology, Bluetooth technology and so on. Modern logistics activity has various forms, such as operation and management in production logistics within an area coverage, transportation and control of logistics lines in a wider area, logistics planning and management in an intelligent logistics center. Faced with these complex things, all kinds of technologies should be used synthetically during the connection process of logistics. The enterprise internal LAN, which always has extended interface to connect with Internet, is often used to manage and operate local logistics. Wireless LAN can be used to replace internal LAN if it is inconvenient to wire in the enterprise. Internet, GPS, GIS are often used together to make freight car networking in order to transport, allocate and manage logistics intelligently, visually and automatically during the wide range logistics transportation management. Field bus technology, WLAN, LAN and other network techniques are often used in logistics center, whose main work is storage.

Wireless communication technology, 3G technology and M2M technology are often used in network communication. Generally the content connection is realized by the usage of LAN, WLAN, Internet, field bus and wireless communication technology.

The operation procedure of modern logistics system is complex, which consists of package, storage, transportation, sort and exchange. Not only information flow, but also capital flow and merchant flow are included in this system. The Intelligence technologies involved are wide ranged and complex. ERP, automatic control and expert system are often used in production logistic inside an enterprise. Data mining, intelligent scheduling, optimization strategy are often used in a wide range social logistics. Automatic control, intelligent robot, intelligent information management system, mobile computing, and data mining are often used in intelligent logistics center. Intelligent computing, cloud computing, data mining and expert system are often used in intelligent supply chain integrated system and logistic public information platform.

Generally these intelligent technologies are often used in intelligent logistics industry, such as intelligent computation, cloud computing, mobile computing, ERP, data mining and expert system.

4. SYSTEM ARCHITECTURE FOR LOGISTICS SURVEILLANCE WITH TECHNOLOGY OF IOT

Taking the tobacco logistics in Wuhan City as an example, WTLDC uses more than 50 vehicles to deliver cigarette packages every day to over 13,000 stores located in Wuhan City with a population of over 9.6 million and an area size of 8494 square kilometers. Each package contains various brands of products in cartons. The customers place their orders through Call Center every day. The order information is entered into an ERP system, and all orders are picked and packed at the distribution center. The packages are of different size, and a RFID tag is attached on each package. Finally, these cigarette packages are loaded into vehicles and delivered to customers' stores. Tobacco is a strictly controlled merchandize by authorities, so we designed this system to monitor the entire process during cigarette packages loading, delivery and unloading. Fig. (**1**) is the general architecture of this system.

As shown in Fig. (**1**), this system includes three parts: (1) Bottom layer is onboard devices, which are used to collect RFID data of cigarette packages and vehicles' GPS information. (2) Middle layer is middleware for IOT, which are used to filter raw RFID data, detect and handle complex RFID events. (3) Upper layer is application software, which subscribes and receives data from middleware, and includes tobacco RFID data management system, Web GIS-based logistics monitoring and scheduling system, etc.

In transit, the onboard devices can scan RFID tags on the cigarette packages automatically with a certain frequency, and then send tag IDs and GPS coordinates to the middleware through 3G wireless network. Then the middleware transmit valid RFID data to upper layer applications after data filtering and events processing. Also, every cigarette package can be scanned when the door of the vehicle is opened to load or unload the packages. Thus, every process, including loading, delivery and unloading, will be monitored totally through this system. As the onboard device, an ARM embedded host, which integrates a RFID reader, a 3G wireless communication module and a GPS module, is installed on the vehicle. Fig. (**2**) is the hardware structure of this device, which includes four parts: (1) RFID reader: scanning and reading tags on the packages. (2) GPS module: receiving coordinates of longitude and latitude from the satellites. (3) 3G module: communicating with 3G wireless network. (4) ARM embedded host: collecting RFID and GPS information and sending them to 3G network.

The ARM microprocessor is extended with related function modules, which are integrated on a printed circuit board (PCB), we call on-board peripheral circuits, such as USB interface, RS232 interface, network interface, LCD controller, keyboard interface, etc. Also, peripheral circuits and core circuits should be separated, thus it would guarantee the microprocessor to run stably, not to subject to external interference in the engineering.
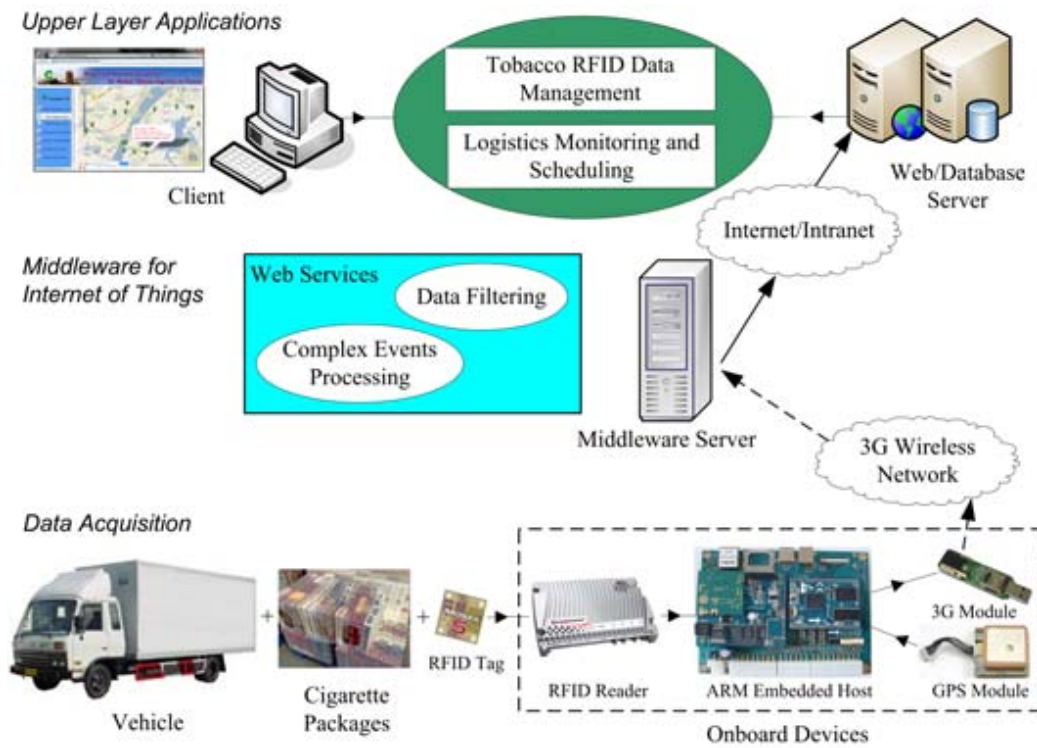
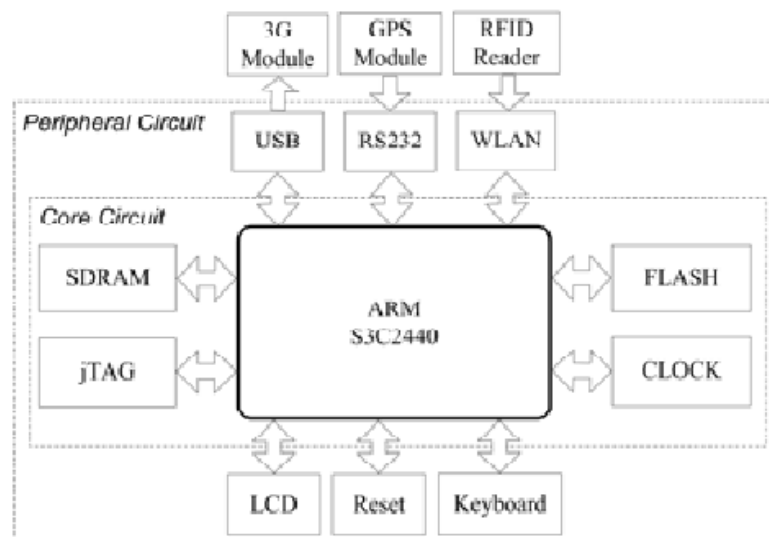**Fig. (1).** General Architecture of Surveillance System.

Fig. (2). Hardware Structure for Onboard Devices.

In core circuit we choose S3C2440 chip, which is based on ARM920t core, as the embedded microprocessor, and choose Linux as on-chip operation system. The ARM microprocessor is extended with related function modules, which are integrated on a printed circuit board (PCB), we call onboard peripheral circuits, such as USB interface, RS232 interface, network interface, LCD controller, keyboard interface, etc. For the sake of stability of the system, it will be better to use on-board peripheral circuits to achieve necessary functions [5]. Also, peripheral circuits and core circuits should be separated, thus it would guarantee the micropro-

cessor to run stably, not to subject to external interference [6]. Large amount of raw data coming from the on-board system, e.g. RFID and GPS data, is short and simple text format. Much of it is not important and has no practical meaning. Only after combining small amount of certain raw data, the system can generate useful information, and prepare them into proper format for the upper level applications to understand. Middleware can process these raw data, and it hides the differences among sensing devices, and provides application developers with a unified interface. Moreover, it can filter and clean massive raw data, collect some useful
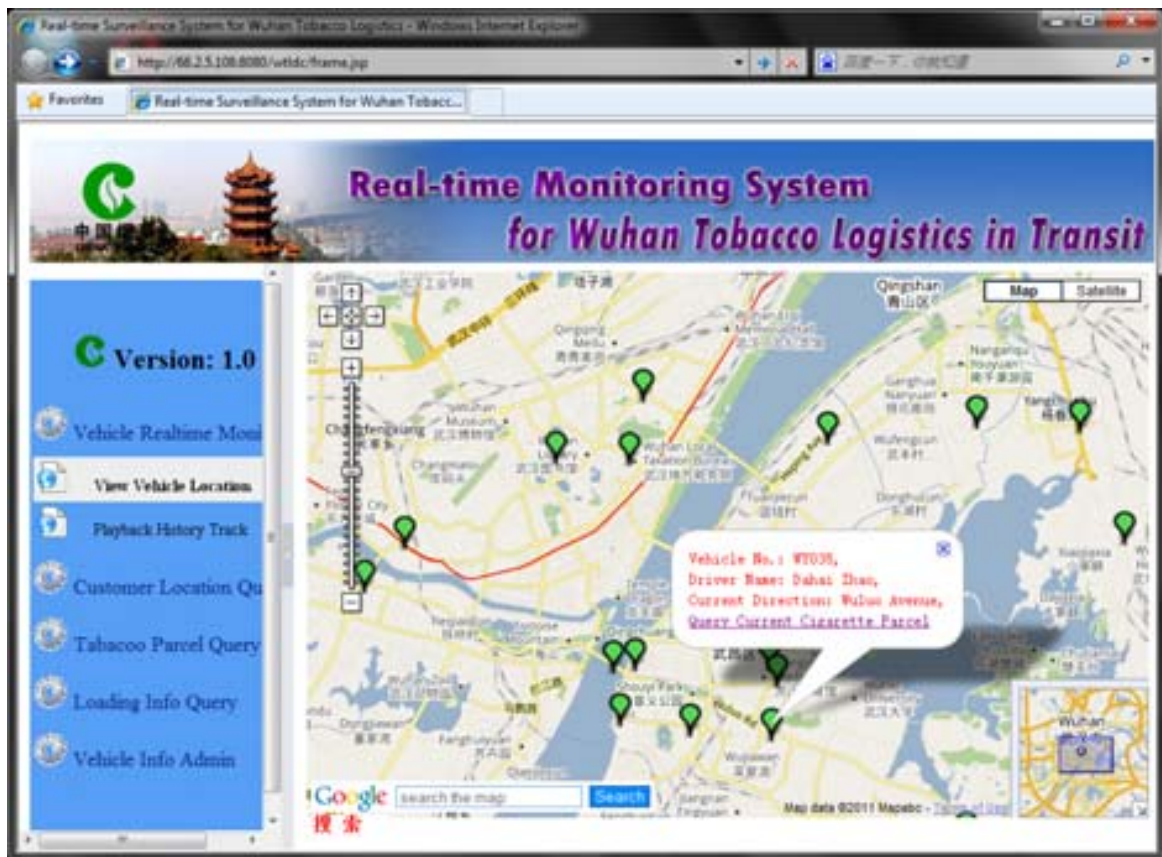
Fig. (3). Main interface of surveillance system.

events and package them into standard format, such as RFID EPC Global and ALE standard [7]. Middleware's main functions include data filtering and complex event processing (CEP), we can encapsulate data filtering algorithm and event detecting algorithm in middleware [8]. Middleware is located between bottom hardware and upper applications, so it is also called middle service layer and can be deployed on application servers to provide services for upper applications.

In the above system (see Fig. **1**), a huge amount of data generated by the RFID reader is filtered and detected by middleware, only a small amount of data is transmitted to upper applications for disposal. Middleware can be implemented with multiple types of technology. In this paper, we use web services, a kind of distributed Internet components which can be deployed on different servers to implement distributed events processing. Monitoring software is SOA), and Google Maps are designed based on service oriented architecture see Fig. **3**). Google Maps API used to show and monitor the location of vehicles is a set of free PIs provided for development of map applications, it allows developers to embed Google Maps in web pages in the case of not creating their own maps server. In addition to help developers to embed maps in web applications, Google Maps API still allow developers to extend an application with JavaScript, such as adding dimension and layer to a map, responding to a user's click action and display the window of objects property on a map.

The onboard devices in a van truck can continuously send packages information and longitude/latitude coordinates of a vehicle to back-end monitoring centers through 3G network, so current locations of all in-transit vehicles may be displayed on a map. When a user needs to query detailed attributes of a vehicle, such as driver's name, vehicle number, current location, package information, etc., he just needs to click the icon of corresponding vehicle on the map, the data will be obtained from middleware and databases, and be displayed on the map at the same time. JavaScript codes included in web pages run in a client's browser, they can request map services with GPS parameters from

Google GIS servers is to through Google Maps API. Once GIS servers receive the request, Google Maps will locate and mark the current location of a vehicle on the map, and then return a vector map to client, so users can see real-time location of the vehicle on the map.

Modern logistics should be the new force to promote the development of modern services as it has quicker reaction, integrated function, serialization service, normalized work, systematic target, modern method, networked organization, marketing organization and electronica information. It is of great theoretical value and realistic meaning to study the multi-dimensional synergy of logistic management in IOT environment.

According to actual needs of the majority of logistics workers and management staff of enterprises and institutions, in addition to problems of existing software systems are bad-

ly in need of upgrading, as well as independence of logistics industry model and complexity of logistics in the process of transporting and control management. These large number of knowledge is classified through theoretical guidance such as information intelligent perception, artificial intelligence, expert systems and knowledge engineering, to sort out their internal relations, and optimize the combination of knowledge based on expression of a variety of methods. With research of the knowledge of high effective tobacco logistics model to build logistics databases, production and processing information database, logistics processing information and manage knowledge database, a shared logistics management information service platform is set up and re-built for the logistics industry to provide assisted strategic supplementary decision for the enterprises and units.

CONCLUSION

IOT brings us a new approach to track and monitor goods in transit, it not only provides the capability of outdoor positioning, but also acquires on-site data to send back to upper applications. In this paper we have presented a solution which integrates RFID/GPS/3G/GIS technologies to implement real-time tracking and monitoring of goods in transit. Compared with traditional logistics tracking systems, it can collect more detailed on-site data at the level of pallets, packages, cases, cartons or items. Based on the proposed solution, we developed an actual monitoring system for WTLDC, from which we find that IOT is a good enabling technology for logistics tracking and surveillance. Monitoring offers not only shipment status in the form of loading, unloading, departure, arrival, and route, but also more value-added, detailed geographical location plus business order information as well as real-time status of goods. It helps improve logistics planning and vehicle controls in logistics. Also it enables better scheduling and improve customers decisions outcome hence minimizing missing goods and reduce wrong delivery.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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