ANALYSIS OF IoT AND SWARM INTELLIGENCE APPLICATION IN VARIOUS FIELDS

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Abstract: The basics of decision theory in the modern world are theories and decision tools paired with the principles and postulates of management science. In this paper, decision support systems are understood as interactive, intelligent computer systems or subsystems that assist the decision maker in the decision making process. An important feature of such systems is that they are based on defined models and algorithms for processing a large amount of data. In principle, such systems can be structured or unstructured. Internet of Intelligent Things (IoT) is a technology that provides efficient connection between the digital and physical worlds, i.e. connecting real-world sensors to the Internet. Swarm-Intelligence Algorithms are used to solve certain, complex problems from practice. The aim of this paper is to define the connection between IoT and Swarm-Intelligence Algorithms and to present the possibilities of application in different fields.

Key words: IoT, swarm intelligence, algorithms, application

1. INTRODUCTION

Internet of Things (IoT) is a set of technologies that enable reading, sensing, processing and remote control of devices using the Internet. Their basic application relates to reading data from the environment and managing intelligent devices over a network. Smart devices or things generate different types of data. Large amounts of data, or Large Data, are transported to the analysis and storage site, where a special cloud computing platform is usually located. Millions of connected devices generate data that needs to be efficiently and safely transported, processed and stored. Therefore, it is necessary to optimize the IoT process and apply intelligent algorithms. Swarm intelligence can be applied in solving various problems in IoT systems. The aim of this paper is to analyze the cause-and-effect relationships between Internet IoT and Swarm-Intelligence algorithms in order to emphasize possible applications in different areas. The following section presents the basic characteristics of the IoT system and swarm intelligence algorithms, together with descriptions of the benefits obtained by applying such intelligent control system.

2. IoT AND SWARM INTELLIGENCE

IoT systems are characterized by data complexity and flow intensity in the process of providing services to end users. Swarm intelligence can be applied in solving various problems in IoT systems. Some essential IoT technologies are presented in Table 1 [1]. Swarm intelligence algorithms can be used to optimize the properties of data manipulation in systems. They can be also applied in data mining to ensure effective data flow.

Table 1. IoT technologies [1]

IoT application	Representative technologies
Transmission	Wireless local area network (WLAN), Bluetooth, ZigBee, Near-field communication (NFC)
Application	Smart cities, Public safety, Industrial monitoring and control, Smart health, Smart agriculture, Environmental monitoring
Perception	QR code, Radio frequency identification (RFID), Wireless sensor networks (WSN), Global positioning system (GPS)
Support	Embedded systems, Cloud computing, Data mining, Artificial intelligence

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In some papers, the authors described and classified the swarm intelligence algorithms applied in IoT systems [2]. The proposed taxonomy consists of five main classes according to their inspiration, and three classes according to their maturity of theory. The algorithms and their applications are presented in Table 2.

Table 2. The swarm intelligence algorithms and IoT applications [2]

Algorithm	Applications
Ant colony optimization	Automatic IoT routing, optimal route prediction, disruption identification, resource indexing optimization, smart vehicle allocation
Particle swarm optimization	Wireless information fusion, sharing information among agents for data mining, fault tolerance routing, resource allocation scheme, cascaded processes control
Artificial bee colony	Service optimization, scheduling for distributed access, handover management, features selection, resolving scheduling problem

Among swarm intelligence algorithms, the most prominent applications in IoT have: ant colony (AC) for data transformation, clustering sensors into classes according to the context, trust value calculation, route ranking; ant colony optimization (ACO) for efficient communities detection, optimal path obtaining, fast schedule obtaining, resource indexing optimization, obtaining efficient route; particle swarm optimization (PSO) for signals fusion, integration of various sensors signals, sharing information and experience, avoiding unnecessary retransmission, control of cascaded processes.

PSO is an algorithm for random global search, consisting of five steps [1]:

- Particle swarm initialization (size, initial particle position, starting velocity);
- Fitness value obtaining for all individual particles;
- Obtaining the best extreme value for individual particle;
- Obtaining the optimal value for the swarm;
- Update the velocity of particles and their position until the exit criterion is not achieved.

Particle velocity and position are calculated as follows:

$$V_{id} = \omega \cdot V_{id} + C_1 \cdot Rnd(0,1) \cdot (Pbest_i - X_{id}) + C_2 \cdot Rnd(0,1) \cdot (Gbest_i - X_{id}) \ldots \quad (1)$$

$$X_{id} = X_{id} + V_{id} \ldots (2)$$

where ω is a non-negative value defining inertia factor, C_i are acceleration constants for individual particle learning and for social learning, $Gbest_i$ is a global optimal position for the search, while $Pbest_i$ is an optimal position for individual particle.

During the Ant colony optimization, the pheromones are released on the path and other ants follow the shortest path to the goal. Transition probability calculation formula $P_{ij}^k(t)$ is [1]:

$$P_{ij}^k(t) = \begin{cases} \dfrac{(\tau_{ij}(t))^\alpha \cdot (\eta_{ij}(t))^\beta}{\sum_{s \in J_k(i)} (\tau_{is}(t))^\alpha \cdot (\eta_{is}(t))^\beta}, if\ j \in J_k(i) \\ 0,\ otherwise \end{cases} \ldots \quad (3)$$

Where:

η_{ij} is a heuristic factor based on the reciprocal value of distance between two points *i* and *j*, and

τ_{ij} defines a pheromone on the path between two points *i* and *j*.

The Artificial bee colony simulates the honey collecting activity, with three different categories of bees. During the search, the employed bee determines the food source and obtains the fitness value, the onlooker bee chooses the food source based on the fitness value, while the scouting bee detects randomly the new food source. The whole swarm memorizes the detected food source, and the food collection can be started. The advantage is a fast identification speed, but the problems could be falling into local optimum, resulting in stagnation [1].

In similar researches, the authors identified three specific application domains concerning some real-world problems and application of Swarm Intelligence in IoT systems: connected vehicles routing, data routing in sensor networks, and data optimization in cloud systems. In this case, the application of IoT solutions brings better quality and greater flexibility by applying various measurements, implementing intelligent management and providing communication [3].

The problem of vehicle routing refers to the logistical problem of minimizing the costs of deploying *x* vehicles for the needs of *y* users. When vehicles are connected to the Cloud platform via the Internet, it is possible to read their status and location using sensors on them. The IoT system thus formed enables dynamic monitoring of vehicle operation, determination of the optimal path to the user or fuel station, analysis and prediction of vehicle condition. With the introduction of autonomous vehicles, all this becomes even more important [4]. A large amount of data needs to be processed in order to enable decision-making in such a system to timely use a dynamic map, and the vehicle to reach its destination safely. Ant Colony Optimization algorithms are used to define and improve vehicle routes [5, 6].

A very similar problem occurs with data transmission in systems with a distributed sensor network, where it is necessary to define the optimal data path from the source to the destination where its user is located, as shown in Figure 1 [7].

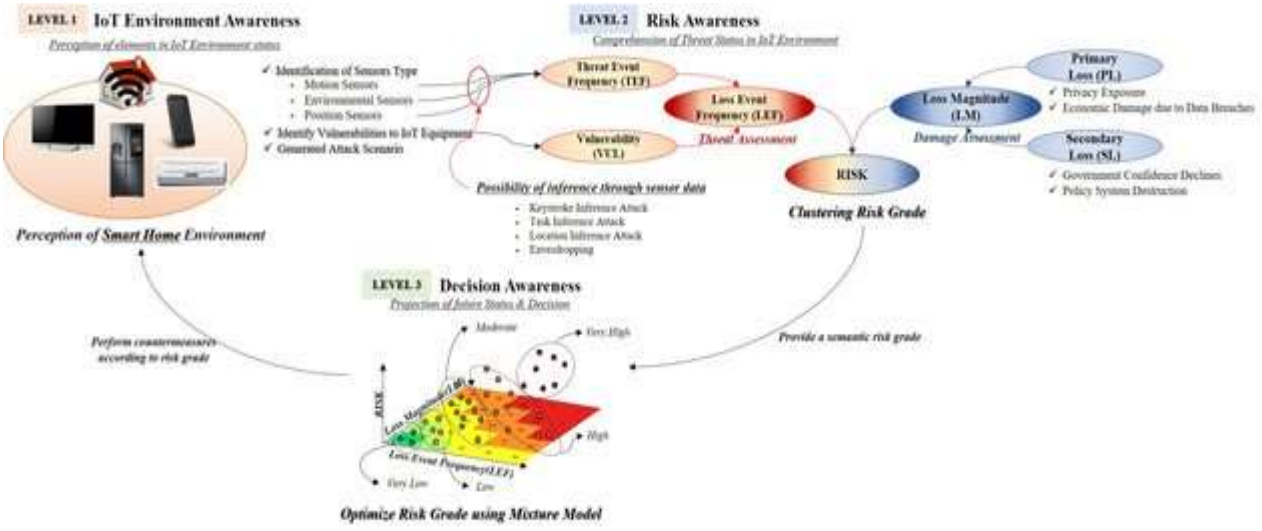

Figure 1 – IoT and environment, risk and decision awareness [7]

Intelligent data routing from a large number of sensors is required to deliver data to end users in a fast and secure manner. Swarm intelligence prevents data loss through efficient routing and data storage [8]. The AntNet routing algorithm uses agents (ants) that analyze the network from each node at defined time intervals, to determine the path to the destination based on the routing table, which is taken over by the previous node after the next node identifies the destination.

The main advantages of IoT are the improved possibilities of collecting, processing, storing and using the collected data. A large amount of data requires special processing algorithms to reduce processing time [9]. This requires finding an efficient and reliable solution for IoT system data optimization. Ant Colony Optimization can be used for this. This allows rapid identification of data

from a large data set, with multi-objective performance optimization and handling of dynamic data with different data sources [3, 10].

3. CONCLUSIONS

The fact is that we live in an era in which the richness of data and the growth in the development of new knowledge is a challenge for understanding and using these tools. The application of the Internet of intelligent devices has recently become especially popular in a number of different areas: logistics, protection of the environment and the working environment, smart energy networks, smart cities, etc. Approaches to solving these problems have evolved over time and have always been greatly influenced by current technical advances. Therefore, it can be expected that the Internet of Intelligent Devices (IoT) as a fairly new concept will initiate the improvement of existing and encourage the development of new solutions.

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