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Cognitive decision making in smart industry

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ABSTRACT

A smart industry integrates ubiquitous sensing capabilities of Internet of Things (IoT) with industrial infrastructure in order to automate various industrial operations. The data collected by IoT system in smart industry can be used to replace manual employee evaluation system where there are ample chances of biasness. This paper proposes a model for automated performance evaluation of employees in a smart industry. The model uses the data collected by embedded sensors in smart industrial system to identify various industrial activities of employees. The identified activities are then classified as positive, negative and neutral activities. In addition, an employee is said to be participating in an activity if employee and activity are co-located. Therefore, the model collects the location data of every employee using GPS devices and calculates the participation of each employee in each of the identified positive, negative and neutral activities based upon the location data. The information hence obtained is then used to draw cognitive decisions for employees using game theory. The experimental study compares the proposed model with manual employee evaluation system and the results depict performance improvement of proposed model over manual system. The impact of automated system on employees is then evaluated both experimentally and mathematically. The results show that the correct evaluation of employees by the model effectively motivates employees in the favor of industry. Thus, the proposed model effectively and efficiently automates cognitive employee evaluation system and decision making process in smart industry.

1. Introduction

Internet of Things (IoT) is a new paradigm that interconnects various 'uniquely identifiable objects' through sensors, GPS devices, radio frequency identifiers, actuators and other wireless and mobile devices. Industrial IoT [48] is a new term which emerged out of increasing interest of using IoT technologies in industry leading to the term 'smart industry'. In other words, a smart industry is one which forms synergy of devices using Industrial IoT. It plays a crucial role in enhancing the use of computers in industry. For example, the objects equipped with GPS devices and radio tags can be automatically monitored and inventoried by computers leading to efficient material tracking and production line management [4] in industry. The sensors and actuators helps in automating other industrial operations such as environment monitoring [13], safety and security surveillance [31], and others. Such applications automates overall industrial system by connecting various industrial infrastructural objects together. Therefore, the integration of ubiquitous sensing capabilities of IoT devices with industrial infrastructure builds smart industrial environment. The terms 'smart industry' and 'industry' are used interchangeably in this paper to refer to an IoT based industry.

Recent years have seen huge advancements in industrial infrastructure due to IoT technologies. But inspite of such enhancements, most of the industries are still evaluating the performance of their employees manually using the information or feedback provided by their heads or senior officials. The limited level of intelligence of automated systems and their susceptibility to errors when the problem lies outside their scope of knowledge becomes a hindrance for industrialists to shift to automated systems. On the other hand, manual employee evaluation system is susceptible to errors too. For example, it is generally observed that the industry offers a bonus or increment to the employee who performs better. The bonus amount is not rewarded to all the employees but to those whose performance evaluation shows excellent performance. On the other hand, industry usually imposes a fine on the employee for showing delinquency. Therefore, the industry takes decision on which employees are to be rewarded and which ones to be penalized based on the manual performance evaluation which is based on personal views of some senior officers. Since the personal views can be biased and

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may not reflect the actual performance of employee, so the decision taken by industry may not be justified. Hence, there are ample chances of biasness in manual systems where an unfair decision leads to discouragement and dissatisfaction among employees.

Motivated by the above mentioned fact, this paper proposes a game based model which helps smart industry to evaluate its employees efficiently based upon their performance rather than relying on personal views of their higher authorities. The main idea is to take decisions about the performance of employees using data harvested by industrial IoT devices. Here the word 'decision' refers to the action taken in response to the performance of employees. Though the kind of decision to be taken is industry dependent, but this paper assumes that the decision is to be taken for the choice of reward and penalization strategies for employee actions. The decision is taken by the proposed model using game theory. The learning capability of game based model provides cognitive capabilities [46] to smart industry. Hence, the decision taken by game model is referred as 'cognitive decision'.

In the light of above, the objectives of the paper can be listed as: (i) to use IoT technologies for collecting data about the employee activities, (ii) to evaluate the performance of each employee using IoT data, and (iii) to take cognitive decisions for each employee based upon their performance using game theory. In a nutshell, this paper proposes a game based model which is capable of taking cognitive decisions in a smart industry.

The remainder of the paper is organized as follows. Section 2 investigates work related to industrial IoT, decision making and game theory. Sections 3 and 4 present the modeling of smart industrial environment and its detailed explanation. Section 5 provides the experimental evaluation of the system and discusses the results. Section 6 presents mathematical results to show the impact of proposed system on employees' performance. Lastly, Section 7 concludes the paper and provides future work.

2. Related work

The ubiquity and pervasiveness of IoT devices in industry offer smart solutions to industrial problems in various domains [24] due to which Industrial IoT systems are gaining momentum. Industrial IoT environment is created by implantation of IoT devices in industrial infrastructure. The growing popularity of Industrial IoT is highlighted in a survey by the authors in [48]. Many other authors have used IoT in various applications of industry such as supply chain management [44], product life cycle management [25–26], quality management [32], and many others [11–12,22,30,34,41,43]. Data generated by industrial IoT devices need to be processed and converted to information and knowledge. The process of conversion of data into information is realized by various data mining algorithms. The authors in Ref. [42] summarized the various data mining approaches which can be used in IoT environment.

The information, obtained after data mining, can be further used in effective decision making process. The authors in Refs. [3,36,39,49] have treated decision making systems in different fields. According to Wu et al. [47], when data acquired by IoT devices is used in cognitive decision making process, then the system is called cognitive IoT which can be effectively used in industrial systems. Cognitive IoT have also been discussed by various authors in Refs. [1,14,15,18,45,50]. Different models are used by authors for decision making such as consensus model [27], agent based model [38], Bayesian decision making model [37], neural networks [40], game model [10], and many more [5,19,23]. Game theory [33] is one of the decision making models which has been extensively used by various authors in literature. Work has been done on game based learning by the authors in Refs. [8,28]. Game model had also been used in industrial decision making process as illustrated by the authors in Refs. [6,7,29] and in cloud computing environment by the authors in Refs. [35] and [2]. Very little work is dedicated to the use of game theory in IoT. In 2014, Fuhong et al. [17] studied the tradeoff between bandwidth and energy consumption in IoT environment using game theory. In 2013, Ding et al. [9] worked towards the security of the IoT network using game theory. In 2014, Hamdi and Abie [20] proposed a security model for the IoT application in eHealth. In all these papers, the authors found the solutions and equilibrium status of the systems under consideration.

All the aforementioned studies discussed various methods to use game theory in industry and IoT but, to the best of our knowledge, none of the authors discussed game theoretic decision making

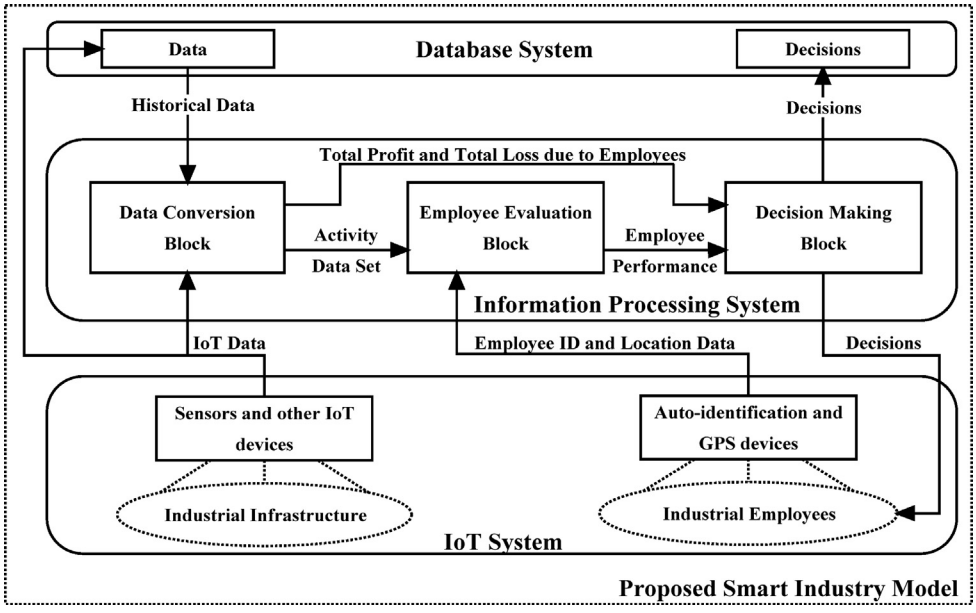

Fig. 1. System flow in the proposed model.