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Crowd science and engineering: concept and research framework

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Abstract

Purpose – The synthetic application and interaction of/between the internet, Internet of Things, cloud computing, big data, Industry 4.0 and other new patterns and new technologies shall breed future Web-based industrial operation system and social operation management patterns, manifesting as a crowd cyber eco-system composed of multiple interconnected intelligent agents (enterprises, individuals and governmental agencies) and its dynamic behaviors. This paper aims to explore the basic principles and laws of such a system and its behavior.

Design/methodology/approach – The authors propose the concepts of crowd science and engineering (CSE) and expound its main content, thus forming a research framework of theories and methodologies of crowd science.

Findings – CSE is expected to substantially promote the formation and development of crowd science and thus lay a foundation for the advancement of Web-based industrial operation system and social operation management patterns.

Originality/value – This paper is the first one to propose the concepts of CSE, which lights the beacon for the future research in this area.

Keywords Transaction, Intelligence, Crowd science, Stability, Ecology and evolution, Modelling and simulation

Paper type Conceptual paper

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1. Introduction

Following the first industrial revolution marked by the invention of steam engine and the second industrial revolution marked by the invention of electric power, man has ushered in the third industrial revolution with the internet as the symbol. Compared with the first two, the third one is transforming the industrial forms and social operation patterns of the human society in a more comprehensive and fundamental way. The underlying reason is that the internet has ignited man's demand and unleashed potential needs of humans, thus having formed the motive power for internet, changing industry and social operation mode.

With a great prospect for integrated development in various fields, the internet is exerting overall and strategic impact on the economic and social development of various countries. For this reason, major developed economies have drawn up corresponding measures to gain the power of initiative in future competition, for instance, Industry 4.0 in Germany and Industry Internet in the USA. Meanwhile, the internet-based economy represented by E-commerce has sprung up in China, extending from consumption to industry, taking on robust power in ensuring economic growth, rebuilding economic structure, stabilizing employment and promoting innovations. Chinese government has in a timely manner made a series of policies and strategies to promote E-commerce, Internet Plus, Internet of Things (IOT), big data, cloud computing, mass entrepreneurship and innovation, crowd making, crowd sourcing, crowd supporting and crowd funding, China Manufacturing 2025 Development Program, etc.

A comprehensive survey of the policies, measures and action plans of various nations finds that most of them are advancing the work through the perspectives of the internet, IOT, cloud computing, big data, Industry 4.0, etc. As a matter of fact, the synthetic application and interaction of/between the above-mentioned new patterns and new technologies shall breed future Web-based industrial operation systems and social operation management patterns. See Figure 1.

In comparison with traditional industrial operation systems, future Web-based industrial operation systems take on the following essential features: initiative, personalized consumption, immediacy, centralized circulation, decentralization, smart production, self-organization and ecologicalized system.

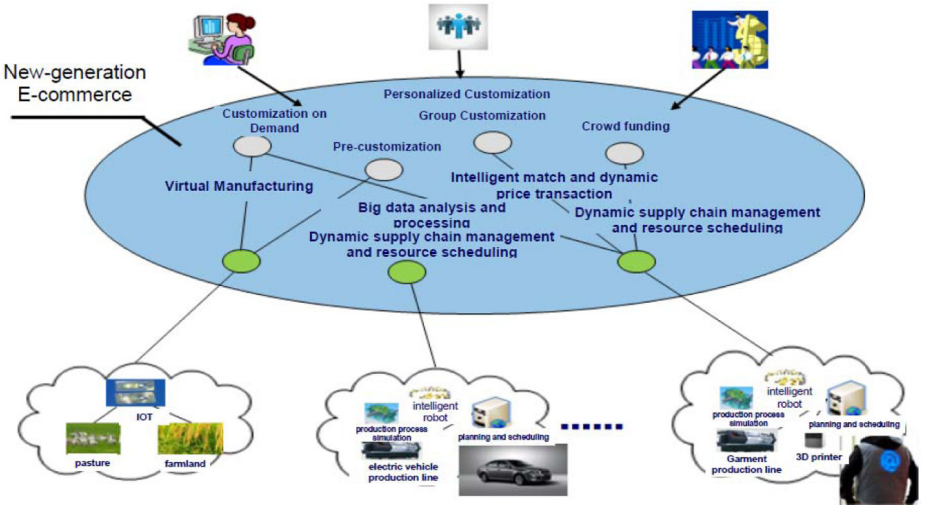

Figure 1. Future Web-based industrial operation system

2. The concept of crowd science and engineering

A deep analysis of general types and substantive characteristics of future Web-based industrial operation systems can easily identify a smart interconnected network system that takes on the features of large scale, openness, self-organization and ecologicalization. Hence, the system is called "Crowd cyber System" in short, as shown in Figure 2. In terms of components, this kind of network systems take the forms of smart entities composed of a great many intelligently interconnected individuals, enterprises, governmental agencies and articles, with sort of supply–demand relationship between them. In terms of major behaviors on the network, the interaction between any smart entities boils down to some sort of transaction or behavior. From the perspective of system, the network system is a ternary system of information, physics and society. Openness, interconnection, cooperation and sharing constitute the basic logic of the network system while stability, efficiency, innovation and development are the targets the system aims to fulfill.

The numerous intelligent agents (enterprises, institutions, individuals and articles, etc.) in the crowd cyber system can give full play to their wisdom and potentiality, interact with each other and produce various kinds of unexpected nonlinear behaviors and effects, which cannot be explained by an existing discipline, but rather need the basic theories and frontier achievements of multiple disciplines. Therefore, an emerging interdiscipline is needed.

Therefore, we propose the concept of "crowd science and engineering" (CSE). Using knowledge of system theory, information theory, cybernetics, computer science and engineering, management, economics, sociology, psychology, as well as the new technological means of IOT, cloud computing, big data, artificial intelligence, CSE aims to explore the basic principles and laws of the swarm intelligence activities of the ternary system of information, physics and society in the context of large-scale online interconnection. In so doing, it seeks to establish related methods and tools, give full play to individual and group wisdom of mankind, tap into the potentials and effectively advance a new Web-based industrial operation system and social operation management patterns.

With crowd cyber system as the object of study, crowd science aims to establish the system of concepts of the crowd cyber system featuring stability, efficiency, innovation and

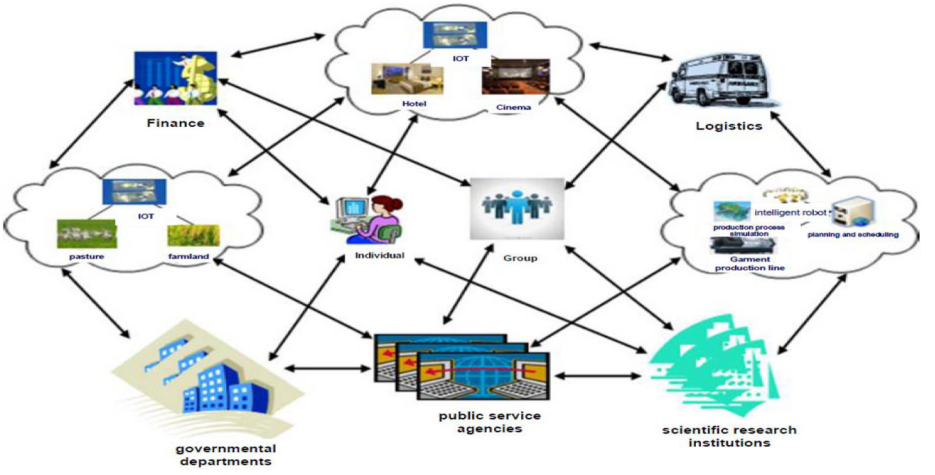

Figure 2.
Schematic diagram of crowd cyber system

development, the basic principles, behavior patterns and related methodologies, thus laying a solid foundation for the Web-based industry.

The essential questions to be addressed include:

Q1. How to construct the crowd cyber system to realize a synchronic mapping in structure, information, behavior and consciousness between individuals, enterprises, governmental agencies and articles of the physical world and various corresponding intelligent agents in the information world, and support various kind of intelligent transaction behaviors between intelligent agents.

Q2. What kind of eco-structure and behavior mode will the multiple intelligent agents take on to ensure the efficient operation of the network system?

Q3. The originality of the crowd cyber system rests with the multitude of its intelligence. What is intelligence? How to measure it? What is the relationship between group intelligence and individual intelligence of various intelligent agents? How to make use of the group intelligence of the crowd cyber system to measure the originality of the network system?

Q4. The sustainability of the crowd cyber system rests with the evolution of various intelligent agents. What are the mechanisms, ways, orientations and conditions of various intelligent agents in the system? How to maintain the rational evolution of various intelligent agents so as to arrive at the sustainable development of the network system?

Q5. How to maintain the relative stability of the network system and rule out breakdowns? This, in the real world, means to avoid destructive "bubble economy", "economic crisis" and "subversive revolution".

3. The research framework of crowd science and engineering

To answer the basic questions mentioned above, the research on the theories and methodologies of CSE mainly concerns issues including:

- research on the modeling and simulation of crowd cyber system;
- theoretical research on the structure of crowd cyber eco-system;
- theoretical research on the intelligent transactions of crowd cyber system;
- research on the intelligence measurement methods of crowd cyber system;
- theoretical research on the evolution of crowd cyber system; and
- theoretical research on the stability of crowd cyber system.

3.1 Research on the modeling and simulation of crowd cyber

Mainly dealing with the construction of crowd network, these types of research aim to build the mental models of network for various intelligent agents (individuals, enterprises, governments and things), so as to enable all intelligent agents in cyber space to reflect individuals, enterprises, governments and things in the real world comprehensively, authentically, correctly and simultaneously. Such models refer to analytic models (for computing), static structure models (for building different kinds of systems), dynamic behavior models (for studying the operational rules of systems), presentation models (for

presenting real individuals, enterprises, governments and things in cyber space) and other intelligent interconnected models and algorithms between all intelligent agents.

3.2 Theoretical research on the structure of crowd cyber eco-system

In the future Web-based industrial systems, varied properties and features of industries or services will definitely result in a large number of operation platforms for interconnected web-based industries and thus form an industrial eco-structure. Then, how many platforms are needed to sustain efficient running of specific industrial systems? Should they be comprehensive, semi-professional or professional? These actual questions indicate the necessity of research on the crowd cyber eco-system.

The eco-structure of crowd network is the relationship of division and collaboration between intelligent agents that form the network, while in terms of future Web-based industries, it is industrial organization form. Eco-structure is one of the key factors affecting the efficiency of network operation.

In a certain industrial organization ecological system, each intelligent agent (each market entity) has its corresponding ecological niche, which refers to the sum of an intelligent agent's particular position in time and space and its functional relationship with other agents. The ecological niche and such relationship will change as transaction efficiency changes, leading to eco-structure changes. Specific transaction efficiency goes with its own eco-structure which is the most efficient structure for the operation of crowd cyber or industrial systems. Transaction efficiency is the main inducement to the evolution of eco-structure. That an intelligent agent's ecological niche and its relationship with other agents change after the changing transaction efficiency is in fact a strategy adopted by the agent according to its ecological niche and environmental variation. Therefore, in eco-structure theories, the focuses of research lie in the evolutionary dynamics, mechanisms and paths of the eco-structure.

3.3 Theoretical research on the intelligent transactions of crowd network

The interaction between various intelligent agents that constitute crowd network boils down to some transaction activities or behaviors. A transaction activity involves the supply side, demand side, objects and rules of the transaction. Major problems in intelligent transactions to be tackled include:

- to describe the needs of demand sides accurately and choose the most suitable out of many supply sides;
- to accurately describe the needs of supply sides and choose the most suitable out of many demand sides; and
- to quickly conclude transactions.

To cope with the above problems, the theoretical research on intelligent transactions should focus on the following aspects:

- intelligent methods of acquiring the law of demand and accurate demands;
- intelligent methods of acquiring the law of supply and accurate supplies;
- methods of intelligent matching transactions;
- mechanisms and methods of forming dynamic pricing; and
- methods of evaluating intelligent transactions.

3.4 Research on the intelligence measurement methods of crowd cyber

The purposes of research on the intelligence measurement methods of crowd network are to evaluate the intelligence of individuals and groups and to offer support for evaluating the innovation potential of individuals and groups. The research focuses on the concept of standardized intelligence and the measurement methods of intelligence of individuals and groups.

There is no standardized concept of intelligence at present. Intelligence and its nature have been studied by lots of philosophers and brain scientists all around the world since ancient times but still remain so mysterious that the occurrence intelligence is among the four secrets of nature with other three being the nature of matter, the origin of the universe and the nature of life. We should, on the basis of existing research results, attach a standardized concept to intelligence, which can contribute to quantitative evaluation of intelligence.

Generally speaking, intelligence may be high or low, but to what degree? Related research is short of fruits. We should build a measurement model of individual intelligence to calculate individual intelligence quantitatively. Meanwhile, group intelligence is higher than individual intelligence in most cases. But there is no research explaining the exact difference and the relationships between them. We should build a crowd cyber-based measurement model of intelligence to calculate group intelligence quantitatively.

3.5 Research on the evolution of crowd network

The purpose of researching the co-evolution theories of crowd network is to support the sustainable development of Web-based industries in the future with scientific evidence. To achieve a sustainable development, an industry must, first, create customers' demands; second, satisfy these demands with low cost and high efficiency; and third, get the most out of all resources, particularly physical resources. All of these require continuous innovation on products and services, improvement in manufacturing or service process and reduction in wastes of resources. Such processes of innovation or improvement are manifested as a continuous evolution of specialized knowledge, business process, ways of resource utilization in an environment of market competition, in other words, to sift out those lagging behind and promote those going ahead. Therefore, research on the co-evolution theories of crowd cyber should focus on the following aspects:

- evolution methods of specialized knowledge;
- co-evolution mechanisms and algorithms of business process; and
- evolution mechanisms and algorithms of resource utilization methods.

3.6 Theoretical study on crowd network stability

Stability is the foundation of everything, including the future network-based industry. Of course, the stability in this case is dynamic, as the industry itself is developing. It can be derived from existing research results, and a stable network cannot be established without the following factors:

- enough network nodes; otherwise, a network with every few network nodes could be vulnerable to external interferences, which would ruin the network;
- excellent network connectivity; otherwise, a loose connection among network nodes would result in a quick network partition under external interferences; and

- controllable differences among network nodes; otherwise, the internal imbalance and insoluble contradiction intensification would cause the collapse of the network.

Given the above-mentioned factors, the concept of crowd cyber stability should be raised and regularized, while the crowd cyber stability quantification methods are demonstrated, which provide the basis of network stability evaluation and thus facilitate the establishment of crowd cyber stability model, through which the solution comes out with network stability status and relevant conditions.

Further reading

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