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Bridges the crowd: rim chain framework

Pengze Li, Ran Zhang, Lei Liu and Lizhen Cui
Shandong University, Jinan, China

Qingzhong Li
Compter Science Department, Shandong University, Jinan, China, and

Guangpeng Zhou
Shandong University, Jinan, China

Abstract

Purpose – Science of the Crowd is a new paradigm. The research on the relationship between provision and requirement arising from the behavior of the crowd under the interconnected environment is a promising topic. This paper aims at studying a new type of interconnected architecture.

Design/methodology/approach – This study is a pioneer work on the establishment of a new type of interconnected architecture – rim chain. The rim chain aims at supporting prompt matching between provision and requirements.

Findings – The analytical results suggest that requirements can be fulfilled in accordance with six degrees of separation. In other words, the matching between the requirements and provision takes place with six hops in the rim chain framework.

Originality/value – Knowledge graph is used to implement the rim chain.

Keywords Crowd science, Knowledge graph, Digital-self, Rim chain network

Paper type Research paper

1. Introduction

The ant colony effect in the natural world, the formation of a group of birds flying in the sky, the business management process in economics, the coordinated operation of the industrial chain, social organizations and their collective behavior processes, national elections and public discussion of social and public issues, are all based on the collection of many individual wisdoms, which aim to achieve better results. All of these can be attributed to the Crowd Science. As a new paradigm, Crowd Science focuses on the impact regarding the number of individuals involved, the way and depth of interaction between individuals. The development of network and AI technologies is a thrust of enhancing the interconnection among people, things, organizations and enterprises. Crowd Science studies digital-selfs of people, things, organizations and enterprises in the physical world. The digital-self reflects the behavior, consciousness and information of the

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real-world subject. Crowd Science covers the scientific problem and universal mechanism behind the phenomena above. Interconnected digital-selfs forms the Crowd Network (Chai *et al.*, 2017). Crowd Network explores the basic principles of the interaction among large number of digital-selfs in the three-dimensional fusion space of cyber-physical-psychological space under the large-scale online interconnection environment.

Although there are a large number of interconnection frameworks, traditional frameworks are no longer suitable for crowd science. First, with the rapid development of society, especially in provision-demand matching, individuals will generate a lot of data. Traditional frameworks are not flexible when dealing with large amounts of data. What's more, in digital world, individuals behave differently from how they behave in the physical world. It means that, in digital world, a new form is also needed to represents the individuals in the real world. To address these problems, rim chain is proposed.

Rim chain is a new kind of interconnection architecture. It is constructed to achieve the rapid provision-demand matching based on the knowledge graph technique. In rim chain network, individuals that interact with others are called digital-self. The digital-self is the core in the rim chain network; it maps people, things, organizations and enterprises from the physical world to the digital world. Digital-self is the representation of individuals and can complete transactions simulation automatically. As individuals make transactions every day, the digital-selfs also can interact with each other in the digital world, to complete the transaction. The provision-demand matching is completed during the interactions among the different digital-selfs.

As a core of rim chain network, the digital-self plays an important role on the evolution of the rim chain network. Just as individuals in the real world are constantly changing, the digital-self will change over time. In the process of change, individuals will form new social relationships, so in rim chain network, the digital self will form links in the new circle. As a result, the change of digital-selfs promotes the evolution of the rim chain network.

Like an individual in the real world, the digital-self also has actions and attributes. The transaction is completed by the digital-self in the rim chain network. The digital-self sends out demand messages to search other digital-selfs which can meet its demand. Different digital-selfs contain different knowledge according to the ability of the corresponding individual. And the knowledge can be used in judging whether the digital-self can meet the other digital-self's demand. As the individuals in the physical world changes frequently, the digital-self should adapt to its change and the network also should update itself to adapt to the change.

What's more, in rim chain network, two digital-selfs can also have relations. Just like individuals in the real world form different circles via interactions and relations. For example, they can be relatives, friends, couples, classmates, colleges and etc. The circle is also created the in the rim chain network in the form of a node which connects many digital-selfs. When digital-self sends out demand, the demand is passed to the circle, then the circle will pass the demand information to other digital-selfs which connects to it to check whether any digital-self could accept the demand and provide resources. It is always the case that one demand is unable to be met in the directly linked social circle. The demand information needs to be transported by other digital-selfs to be fulfilled. The rim chain network possesses the ability to make the demand information further and complete the matching process.

The article is organized as follows: Section 2 discusses related research in framework of the social network, and why these traditional social network are not suitable for the Crowd Science. In Section 3, it discusses the schema of the rim chain network model, with the entity, relation and attributes. Section 4 contributes the rim chain network's construction method. Section 5 presents how the rim chain network works in the provision-demand matching, and Section VI draws conclusions.

2. Related works

Crowd Science is a new paradigm. Crowd Science studies digital-selfs of people, things, organizations and enterprises in the physical world. It is based on the System Theory, Information Theory, Cybernetics, Computer Science and Engineering, Management, Economics, Sociology, Psychology and other subjects, and becomes a new interdisciplinary direction (Kutsenok, 2004). The Crowd Science uses the Internet of things, big data, cloud computing, artificial intelligence and other new technologies to access and analyze the data of public behavior with the ternary fusion system of information physical society and studies the basic principles and laws of intelligent crowds' activities in the new social model. Recent years, intelligence networks or crowd networks have been studied to promote the development of crowd science by exploring crowds' behaviors.

Interconnected digital-selfs form the Crowd Network. Social networks have become complicated due to the complexity of human activities. Many studies in this field of social network use the basic elements such as people, company, shared interest as the node and use the relationship between elements as the relation or the edge of the graph. The graph theory makes great contribution to these studies. As the size of the network continues to expand, the network structure will become more complex. Researchers look forward to finding a universal structure in a variety of applications.

So far, there have been studies on intelligence networks or crowd intelligence at home and abroad, but all these studies are fragmented and incomplete. Many researchers have studies Swarm AI, a relatively new Artificial Intelligence method. Swarm AI involves multiple agents operating in an environment to solve problems through cooperation (Kutsenok, 2004). It focuses on the optimization of complex problems. Compared with Swarm AI, Crowd Science focus on the country's major strategic needs and solves the basic problems of future networked, intellectually-oriented economy and society. However, both draw lessons from group insects. Crowd Intelligence (Li *et al.*, 2017) is the collective wisdom of a large number of autonomous individuals. In an internet-based organizational structure, these autonomous individuals jointly complete challenging computing tasks. The research objects of Crowd Intelligence are homogenous while the research objects of Crowd Science are heterogeneous including individuals, enterprises, governments and things. Collective Intelligence (Pierre, 1997; Lévy, 1997) is a form of subjective mobilization, highly individual as well as ethical and cooperative under the natural environment and the scale of the research object size is limited; however, Crowd Science works on large-scale individuals, companies, institutions and other things in the online and in-depth connected public Crowd Network, under the internet and big data environment.

There are two kinds of representative network frameworks, framework from Sentinel Visualizera and the framework from the ICTA. This paper will compare rim chain to these two social networks based on the following principles. The rim chain network has two principles: It should update timely and continently without low cost; It should clarify the relations among the digital-selfs in the network.

Figure 1 shows the framework of Sentinel Visualizer. It shows the cluster and centrality of the crowd, and uses different colors to measure the range of features, betweenness centrality, degree centrality and etc. This framework is useful for analyzing the closeness of relationships between people and for studying some social phenomena. However, it has some limitations. For example, when it needs to update itself, it has to break the link and add nodes, then relink the circle, the operation is complicated. Other than that, it does not explain why people get together. Although it can display a link information circle at the edge between entities, this can lead to information redundancy.

Figure 2 shows the framework from the ICTA. It is similar with rim chain network structure. It is easy to update. When adding a new node into the network, simply connect the new node to the target node. However, it only has nodes representing people, and the relationship between people is implicit. This kind of network framework is good representation of online social networks, such as the follow relationship between users in Twitter.

The rim chain network should distinguish between different digital-selfs, especially their abilities and various requirements. Due to the aim of the rim chain network, the digital-selfs can only perform limited functions. It mainly focuses on the provision-demand matching. Moreover, the rim chain network should clearly describe the complicated social relations among the digital-selfs. That is to say, when the rim chain network is visualized, it should reflect the social relations in a reasonable way, and it should be easy to implement when coding the traversal algorithm.

3. Schema of the rim chain network

In this section, schema of the rim chain network is given. The rim chain network shows the relations and interactions between different individuals in the physical world, especially in provision-demand matching. To better and more clearly describe the social network, the

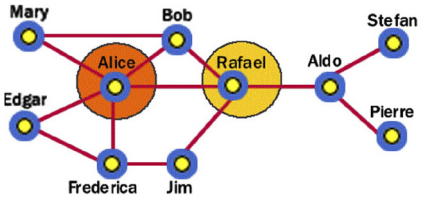

Figure 1.
Network framework form Sentinel Visualizer

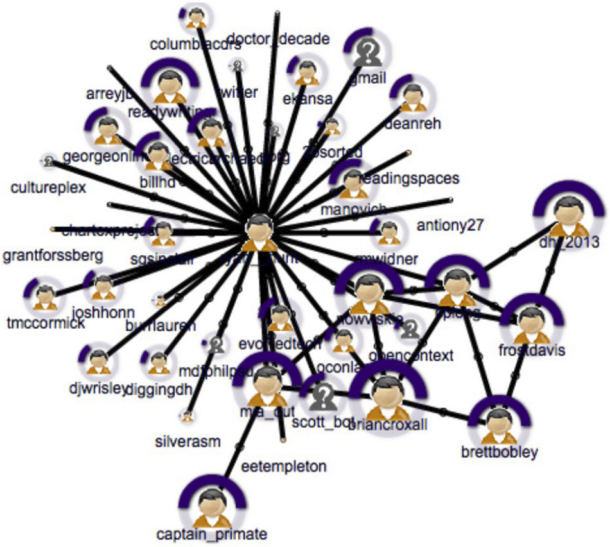

Figure 2.
Network framework from ICTA (internet community text analyzer)

graph theory is used in this paper. The rim chain network is constructed with digital-self node, circle node, the relation link between them and their attributes.

Figure 3 is the schematic diagram of the rim chain network consisting of business cards, each of which represents a digital self. In this schematic diagram, the digital-selfs are in different circles, and they can join more than one circle. The icon in the center of the circle means the theme of the circle, which is the reason why different digital-selfs are connected together. The following will detail the digital-selfs, circles and relationships in rim chain network.

3.1 Digital-self

The digital-self is the mapping of people, things, organizations and businesses from the physical world to the digital world. The digital-self is autonomous, which means that when the edge chain network is active, it can control its behavior and update its attributes without manual intervention. More importantly, it can proactively handle provision-demand matching without manual intervention. The process of provision-demand matching is similar to the exchange of information among digital-selfs.

It has four attributes, namely, Identification, Supply, Requirement and Circle. These four attributes are further divided into dynamic attributes and static attributes. Dynamic attributes tend to change over time. Static attributes are attributes that change less. Identification refers to who is the digital-self, Supply refers to what the digital-self can provide, requirement refers to what the digital-self needs and circle describes the social relationship of the digital-self. The attributes can be considered knowledge. Although a digital-self can have a variety of knowledge, nobody can see it. Only the digital-self that belongs to the same circle as the knowledge owner can see the knowledge directly related to the circle theme.

As the digital-self is the mapping from the real world, the digital-self has behaviors. The digital-selfs can send out requirement information and accept the requirement from other digital-selfs based on its knowledge and willingness. The willingness will be mentioned in the fifth section. In addition, everyone changes every day, for example, people can acquire new skills, have new requirements and join new circles. Therefore it also should have the ability to update itself. All of these can be and should be reflected in attributes and the rim chain network structure.

3.2 Circle

The circle is also considered a node. It describes why the digital-selfs are connected to it. Due to the homogeneity of certain attributes of the digital-self, different digital-selfs are connected to the same circle. Note that the circle node has properties that display its theme.

Figure 3.
The schematic diagram of the rim chain network

This concept draws on the social circle of the physical world. A circle node functions is similar to a router, meaning that it can plan a path for requirement information. It can guide how the requirement message is transmitted in the rim chain network.

The circle node has two attributes, digital-self type and theme. The digital-self type describes whether the digital-selfs contained in this circle is an individual, an enterprise, a government or a thing. Theme is the theme of the circle. The circle nodes are regarded as important routing nodes.According to the digital-self sender, find all the circle nodes connected to it; first, if the type of digital-selfs in the circle does not match the requirement. For example, you need to query the teacher. If there are only enterprises in it, then the type of digital-selfs in the circle does not match the requirement. Second, if the theme of the circle node does not match the keyword of requirement, the requirement information will not be matched with the digital-selfs which connected to this circle node. The requirement information is sent directly to all remaining circle nodes via the digital-self nodes connected to the circle node. As nodes can be accessed multiple times, hash maps can be used to avoid duplicate access. Finally, three degrees of influence theory is used to limit the number of nodes that can be accessed and avoids accessing too many nodes.

To meet the requirements, the circle node should find the digital-self that is most likely to meet the requirement. If the digital-self directly linked to the circle node does not meet the requirements, then the circle node should further propagate the requirement information. This is an important function of the circle node and a basic function for matching provision-demand matching.

What's more, the circle node limits digital-selfs' behaviors. All the digital-selfs cannot interact with each other directly. This feature makes transactional queries more efficient. The digital-self only needs to send their requirement information to the circle node that is linked to itself.

When the circle node receives the demand information from the digital-self, it will get the keyword of the requirement, and try to find the best digital-self to meet the requirement. The matching is based on the circle's theme. For example, it is easier to find a professor majored in computer science in a university computer science college circle. If there is no perfect match, the circle node will continue to forward the requirement data to other nodes.

3.3 Relation

The concept of relation contains various kinds of social structure in the real world, such as communities formed by people of common interest, or hierarchical structures that are common in companies. The relation notation is used not only to realize the mapping of people's various social structures but also to provide provision-demand matching with directions and paths in the rim chain network. It is either the skeleton of the rim chain network or the fundament of the provision-demand matching. The demand information possesses directionality, and it can be forwarded via different paths, which is the relation link in the rim chain network.

The relation is a link between the digital-self node and the circle node. It can be understood simply as 'in' from the literal meaning. It is denoted as an arrow pointing from the digital-self node to the circle node. The rim chain network's traversal is established on this link.

4. Process of constructing the rim chain network

This section describes the process of constructing the rim chain network. When constructing the rim chain network, the content of the database is first extracted. Then the digital-selfs and circles are formed based on the data. The data in the database also contain

the relationship between digital-selfs. The link between digital-selfs and circles comes from these relationships. After the completion of the construction of the relationship between digital-selfs and circles, the construction of rim chain network is completed (Figure 4).

Constructing the rim chain network requires two kinds of the data. The first kind is the basic information of the digital-self. Such as the name, city, location, etc. This will be used as the attributes of the digital-self. Another one is the social relation. It is used to collect the circles' information and to build the link between digital-selfs and the circles.

In general, there are four types of information that need to be reflected in the rim chain network. First, ID is used to distinguish one digital-self from the other, telling the rim chain network about who is the digital-self. The second one is the provision information; it tells what services it can provide for other digital-selfs. The third one is requirement information, which will generate detailed and accurate demand information, when the digital-self has a demand. The last is circle information, which describes the digital-self's social relations, and which circle this digital-self should belong to. A digital-self usually belongs to more than one circle. The database used in this article directly provides the above attributes.

Data can be acquired through machine learning, data mining and natural language processing. The data format is initially inconsistent, and therefore needs to be integrated so that the data can be a useful form. After the data preprocess, the information is placed in a relational database. The corresponding relationship between fields in the database schema and digital-self's attributes is shown in Figure 5.

The database schema in Figure 5 takes a company as an example. This is a company that processes electronic components. The database schema lists some of the company's attributes, such as the company's ID, business scope, raw materials and the company's location. When the company is mapped to the digital-self, its attributes are converted into digital-self's corresponding attributes. In this example, the company's number indicates the digital-self's ID. The company's business scope is the company's provision for other digital-selfs. The raw material is the company's demand. The company's location is the attribute that associates with other digital-selfs.

After completing the migration from relational database to neo4j, an interconnection network structure will be established in neo4j. Figure 6 shows the schematic diagram of the rim chain network. This kind of framework is chosen rather than a link circle, because this framework is more flexible. When adding a new digital-self into the network, there is no

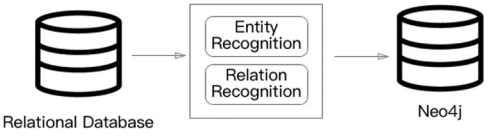

Figure 4.
Data extraction from RDB to Neo4j

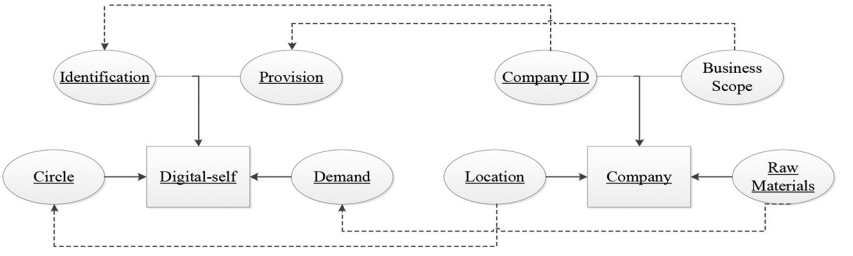

Figure 5.
The dgital self's attributes and the database schema

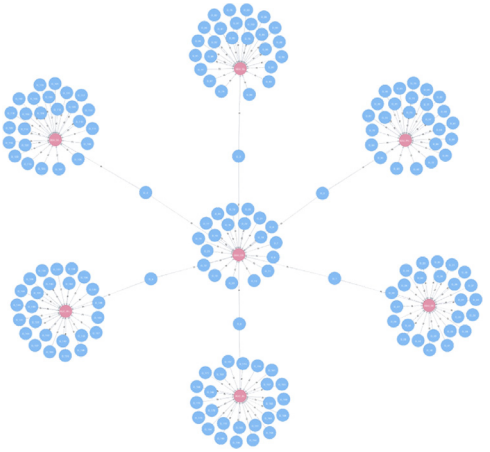

Figure 6.
The schematic diagram of the rim chain network in Neo4j

need to break the link circle, but directly connect the new digital-self to the target circle. Although in Neo4j's visualization, it is not a circular chain network structure, it is logically equivalent to a circular chain network structure. At the same time, this architecture also uses Knowledge Graph. The Knowledge Graph includes entities, attributes, and relationships. In the rim chain network, the concept of digital-self corresponds to entity, and all properties of digital-selfs, circles and edges correspond to attributes in the Knowledge Graph.

In Neo4j, digital-selfs and circles can all be represented by nodes. The relationship between them can be represented by graph edges. At the same time, both the node and the edge can contain certain attributes, thus laying the foundation for the construction of the rim chain network. As the digital self has behaviors and attributes, after creating the digital-self, object-oriented techniques can be used.

Algorithm1. Create the rim chain network.

Input: The people, organizations/institutions, things and enterprises data in the database.

Output: The rim chain network.

```
initialize data from database
initialize array D[digital_self_num]
for index ←1 to digital_self_num do
        initialize digital-self d1
        D[index]←d1
end for |
initialize hash map C
for index←1 to digital_self_num do
        initialize circle node c1
        C ← c1
end for
for i ← 1 to digital_self_num do
        for each circle node information in D[i] do
            if circle node information exists in the hash map C then
                        create link from D[i] to the circle node
                else
```

```
17:                         create new circle node c
18:                             create link from D[i] to the circle node
19:                             C ← c
20:                     end if
21:             end for
22: end for
```

5. Provision-demand matching in algorithm

The provision-demand matching algorithm is based on the structure of the rim chain network. The rim chain network accurately, simultaneously and comprehensively describes the people, organizations/institutions, things and enterprises in the real world. Moreover, the static structure of the rim chain network is used to achieve a robust social network system. The rim chain network should be able to create the digital-selfs' needs while creating the basic structure. The process of meeting the requirements is cost effective when a new piece of requirement information is sent out from a digital-self. Because when more and more people, organizations/institutions, things and enterprises in the real world enter the rim chain network, its scale will continue to increase. There will be millions of entities (people, institutions, things and enterprises) and their attributes when the rim chain becomes very large. During the provision-demand matching, the comparison has to be done between the requirement and supply information provided by different digital-selfs. However, comparing the supply information one by one is time-consuming because one digital-self can have more than one attributes. Therefore, the matching algorithm has to deal with the rim chain network's size problem.

As shown in the algorithm flow in Figure 7, when the rim chain network executing the provision-demand matching function, it only need compare the keywords in the requirement information with the theme word of the circle node. As the digital-selfs with the same subject are connected to the same circle node, and the circle node has the attributes which

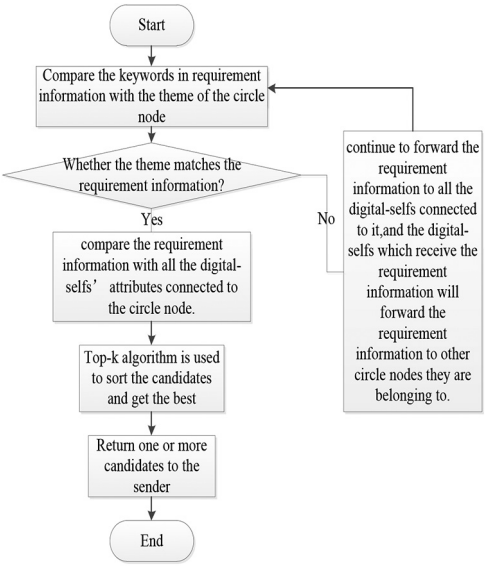

Figure 7.
The algorithm flow of the provision-demand matching algorithm

describe the theme of the circle, that is, the reason why the digital-selfs get together. According to the formal definition, for digital-selfs, only the attributes related to the circle's theme can be compared. As a result, if the circle's theme matches the requirement information, the rim chain network will compare the requirement information with all the digital-selfs' attributes connected to the circle node. Probably, there will be more than one candidate. Then all the candidates are selected, and a top-k algorithm is used to sort the candidates and get the best one. The algorithm not only considers the provision-demand issue, but also other factors that could influence the transaction, after a comprehensive consideration, the rim chain network will return the best target digital-self to the requirement sender. If the requirement sender desires more than one target digital-selfs, the rim chain network will return all the candidates to the sender. If the circle node's theme does not match the requirement information, it only need continue to forward the requirement information to all the digital-selfs connected to it. And the digital-selfs which receive the requirement information will forward the requirement information to other circle nodes they are belonging to. Then the rim chain network repeats the comparison with the circle node's theme. The process is not endless due to the six degree of separation. The process of provision-demand matching is given as following.

When people, institutions, things and enterprises, in the real world have a need, the digital-self will send out a message, including the vital information about the need. This is significant for the matching process; the digital-self should ensure that the need information is valid and unambiguous.

Usually a digital-self is involved in many circles. Because digital-selfs cannot interact with each other directly, the information is passed to the direct linked circle nodes. Then, the information is forwarded to the digital-selfs linked to the circles in the previous step. These two steps will be repeated until any digital-self accepts the need. During the matching process, the need information will be compared to the digital-self's knowledge; it can only see the knowledge related to the circle theme. This can be viewed as the security requirement. What is more, the information passing is not endless. From the six degree of separation, the influence from people's action is no longer meaningful at a social horizon of six degrees. The maximum epoch times is six, based on the six degree of separation. If after six epochs, there is still no digital-self to confirm the need, then the need information will be abandoned and give the digital-self a feedback to make it aware of the situation.

6. Conclusion

This paper proposes a new interconnection framework to achieve the provision-demand matching activity in the digital world by using the knowledge graph and the data acquisition methods.

The transactions in real life are often one-on-one transactions, due to the limit of a variety of conditions. As a result, it is hard to shop around to find the most cost-effective transactions. While in the rim chain network, the process of shopping around is automated, the digital-self can achieve one-on-many or many-on-many transactions.

An important part of the Crowd Science is the intelligent matching of transactions, from describing information on both sides of provision and demand, to quickly finding the right target for transactions. As a new type of interconnected structure in the field of Crowd Science, rim chain network has a certain degree of help in transactions matching and mapping the physical world to the digital world.

The rim chain network is suitable for transaction matching in the real world and can help individuals, enterprises, governments and things find suitable transaction targets. Because of the lack of direct link between the demand sender and the best transaction target, the

transactions in physical world usually are hard to complete. But in the rim chain network, the interconnection between the digital-selfs and circles increases the likelihood of successfully completing the transactions.

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Corresponding author
Ran Zhang can be contacted at: zhangran0816@qq.com