A boundary knowledge field based data mining method

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Abstract

Data mining (the analysis step of the "Knowledge Discovery in Databases" process, or KDD), an interdisciplinary subfield of computer science, is the computational process of discovering patterns in large data sets involving methods at the intersection of artificial intelligence, machine learning, statistics, and database systems. Knowledge is the source of getting and keeping the strength of competence, knowledge becomes an important strategic resource at the age of knowledge economy. The way to facilitate knowledge transfer smoothly plays a critical role in determining the competence of an organization or organizational system. To explore the mechanism of knowledge transfer, the characteristics of sticky transfer (flow) is compared with the flow characteristics of viscous fluid, and the knowledge on the theories of field in physics, viscous fluid mechanics and boundary layer is employed and analysed in this paper. Firstly, the concept of boundary layer in the knowledge field is proposed to analyse the difference of knowledge stickiness in the knowledge field and describe the contradictory relationship between knowledge stickiness and liquidity. Secondly, based on the analysis of the knowledge transfer in the boundary layer, the dynamic mechanisms of sticky knowledge transfer are analysed from the three aspects of the knowledge potential difference force, the viscous force and the extern driving force. The rotation mechanism of knowledge in the knowledge field is discussed, and the dynamic model of the boundary layer of knowledge field is built. Finally, the phenomenon of knowledge flowing into and flowing out of boundary layer is discussed, and the knowledge transfer conservation equation in the boundary layer is constructed to describe the updating and appreciation of knowledge in the boundary layer of knowledge field.

Keywords: data mining, knowledge transfer, knowledge field, boundary layer

1 Introduction

The overall goal of the data mining process is to extract information from a data set and transform it into an understandable structure for further use. Aside from the raw analysis step, it involves database and data management aspects, data pre-processing, model and inference considerations, interestingness metrics, complexity considerations, post-processing of discovered structures, visualization, and online updating. Knowledge is distinguished from data and information. The data is organized to produce general information [1], and information has little value in itself until it becomes knowledge as a result of processing by the human mind [2]. For knowledge, it involves a person using his or her perception, skills and experience to process information - thus converting it into the knowledge in the mind of the individual [3]. Knowledge is a vital source for the organizations to gain the advantage in the competition [4]. Ever since the conception of knowledge economy is brought forward by Drucker [5]. The position of knowledge in the development of economy is increasingly gaining more and more attention, and researches have shown that the world economy is driven by the production, transfer, and use of knowledge [6, 7]. In the time of knowledge economy, knowledge transfer and creation are growing more and more important, no matter for individuals, organizations, or even countries [8, 9]. Taking its fluidity into consideration, knowledge is considered to be one fluid and it can transfer among organizations. Therefore, the concept of knowledge transfer is propounded by Teece [10]. He pointed out that it is a process in which knowledge is sent and received back and forth between knowledge senders and receivers [10]. Knowledge transfer is a communication process in which knowledge flows between demanders and producers [11]. It is an important factor for an organization's success [12]. Accordingly, many studies analyzed the factors that affect knowledge transfer, and showed that the knowledge characteristics, such as tacitness, expressiveness and complexity, directly change the process of knowledge transfer (Szulanski, 1996; Zander, 1991; Simonin, 1999) [13-15]. Afterwards Cummings and Teng [16] studied the influences of the expressiveness and embedded-ness of knowledge on knowledge transfer. Then Ajmal & Koskinen (2008) [1] elaborated the knowledge transfer from three perspectives: first, as a solution, knowledge emphasizes the real-time transfer of knowledge among practitioners who are seeking to solve problems or enhance operations; second, as an experience, knowledge describes the progressive process of acquisition and accumulation for the possible use in the future; third, as a social product, knowledge is created and shared through interpersonal relationship and social network.

Due to the fact that knowledge transfer is an essential role for the organizations to gain the advantage in the

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competition, it is very important to accurately describe the transfer mechanism of knowledge in an organizational system [17, 18]. Since the concept of knowledge field (Ba) was proposed by Nonaka and Takeuchi in 1995 [19], the concept gave researchers lots of inspiration on knowledge transfer. Nonaka and Takeuchi [19], additionally, structured the SECI model of knowledge transfer and creation, meanwhile they pointed that knowledge field could provide energy for knowledge transfer and creation and affect the quality of knowledge production. Based on the SECI model of knowledge creation, Ba, which is conceptualized as a shared context in motion, can transcend time, space, and organization boundaries to create knowledge [20]. The theory of knowledge field is widely recognized [21, 22]. Against this background, many researchers have conducted deep research on the transfer mechanism of knowledge based on the concept of "knowledge field". The process and the influence factors of knowledge transfer (flow) are analysed [23, 24]. The view of Nonaka is accepted by Eastern researchers, but the Western pay attention to research the process of knowledge share and based on the organizational theory and the social capital theory analyse the construction of communities of practice and the impact of the knowledge-sharing field (communities of practice) on the organizational performance [25-27].

Throughout the above researches, the knowledge transfer (knowledge flow) and knowledge stickiness have been analysed, which attempt to explain the mechanism of knowledge transfer and the influence mechanism of the stickiness on knowledge transfer. However, most of these investigations mainly focus on qualitative discussion and empirical analysis based on questionnaires. Since the mechanism of knowledge transfer is still not fully understood, there remains a lack of systematically theory and mathematical model to elaborate the process and mechanism of knowledge transfer. As discussed earlier, it is known that knowledge has the properties of stickiness and field. In fluid dynamics, when the fluid flows in the flow field, it has the properties of liquidity and stickiness which make the phenomenon of the boundary layer generated [45, 46]. In 1904 it is the great achievement of Ludwig Prandtl who set forth the concept of boundary layer at the Heidelberg mathematical congress. Prandtl showed that the flow past a body can be divided into two regions: a very thin layer close to the body (boundary layer) where the viscosity is important and the remaining region outside this layer where the viscosity can be neglected [47]. It is confirmed that the appearance of the boundary layer phenomenon is caused by the liquidity, the viscosity and the properties of field. It should be mentioned that knowledge also has these properties in the process of knowledge transfer (flow). It is believed that the mechanism of knowledge flow (knowledge transfer) is similar to that of viscous fluid flow.

Therefore, the study is inspired by viscous fluid mechanics, and the viscous fluid-flow model and the boundary layer theory is employed to describe the process of knowledge transfer in this article. The flow of the sticky knowledge in the knowledge field is explained by the phenomenon of the boundary layer. On this basis, the rotation of knowledge field through the boundary layer phenomenon of knowledge stickiness is analysed. Meanwhile, based on the partial differential theory and the analogy method of viscous fluid dynamics, the dynamic equation and conservation equation of knowledge field are derived in order to analyse the dynamic mechanism of knowledge transfer under the action of different effects and the updating and appreciation of knowledge in the boundary layer of the knowledge field.

2 Boundary layer model of knowledge transfer

In a great deal of previous researches, knowledge transfer is widely recognized as an essential process in which an organization can acquire valuable knowledge to produce knowledge and boost economic performance [28-31]. However, organizational members in their own interest are unwilling to share core information they possess with other members [32]. Thus, it is difficult to effectively achieve the transfer of knowledge among different organizations [14, 33, 34], even among the different departments in an organization. This is, to a large extent, because knowledge has stickiness which severely hinders the transfer of knowledge between knowledge providers and knowledge users [34-36]. The knowledge stickiness can be defined as the extent to which knowledge is unremovable from its originating source [37]. A series of investigations on knowledge stickiness have been conducted by many researches [38-40]. Knowledge stickiness comes from the concept of "sticky information", which was introduced by Von Hippel [38] to describe information that is difficult to transfer. On this basis, Szulanski [14] extend the concept of information stickiness and defined knowledge stickiness as difficulties encountered in the process of knowledge transfer. The above knowledge which is hard to transfer is called sticky knowledge, and it is hard to transfer smoothly than general knowledge (namely, its stickiness is negligible). And then researches have further explored how properties of knowledge influence the transfer of sticky knowledge. Simonin [15] analysed the phenomenon of stickiness in the process of knowledge transfer from the aspects of tacitness, assets specificity, complexity, protection of its owners, cultural and organization distance etc. The "causal ambiguity" of the knowledge or the extent to which it was not well understood predicted the difficulty of transfer throughout all phases of the transfer process [4]. According to the process of knowledge transfer (initiation, implementation, ramp-up and integration), Szulanski [41] also discussed the nature of difficulty caused by stickiness at each stage.

When acknowledged, knowledge can be categorized into tacit knowledge and explicit knowledge [19], the stickiness of tacit knowledge is greater than that of explicit knowledge, and the transfer of tacit knowledge is more difficult. Thus, simple, codified knowledge is easier and

more efficient to transfer than complex, tacit knowledge among members in organizations, and meanwhile to strengthen members' tie can increase the ease and efficacy of transferring complex, tacit, and private knowledge [42, 43]. According to the research of Szulanski and Cappetta et al [44], knowledge stickiness means the difficulty of intra-organization knowledge transfer, and it can weaken the organizational flexibility and reduce the capacity of making full utilization of the knowledge which transfers between the enterprise and its partners. Thus, for an organizational system, the way to transfer the sticky knowledge smoothly plays an important role in improving the efficiency of innovation and keeping strength of competence.

Knowledge has the properties of field, and its distribution is uneven in time and space. In the knowledge field, the potentials of knowledge owners are related to the knowledge stocks that they own, that is, the more knowledge stocks they have, the higher knowledge potential they locate (Wang, Xing & Tang, 2010) [22]. Driven by the fluidity and inhomogeneous distribution of knowledge in the knowledge field, knowledge flows from the area with higher knowledge potential to the area with lower knowledge potential [24], which makes the knowledge providers interacting with knowledge users. In the interacting process, the share, transfer, and production of knowledge are conducted. However, because of its stickiness, knowledge fails to transfer smoothly, namely there are obstacles during the process of sticky knowledge transfer [36, 48, 49].

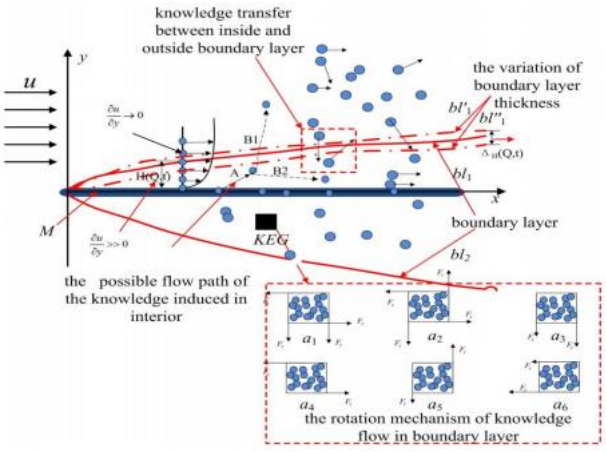

FIGURE 1 Boundary layer model of knowledge transfer

To describe the process of sticky knowledge transfer and to characterize the mechanism of knowledge transfer, the boundary layer model of knowledge field is established when sticky knowledge flows between knowledge providers and knowledge users in the knowledge field. To simplify this model, a two-dimensional knowledge field is employed to describe the boundary layer phenomenon of knowledge field, as the Cartesian coordinate of X-O-Y shown in Figure 1.

In Figure 1, we suppose that the blunt body M represents an organization in the knowledge field, and there is a variety of knowledge in the two-dimensional knowledge field. The circular marks indicate a variety of knowledge that the organization has in the knowledge field. The size of circles mark indicates the stock of one type of knowledge, and the arrows for the circle marks represent the direction of knowledge motion in the knowledge field. The circle marks is also called one knowledge unit in this paper, which is so small that it cannot be divided. Different knowledge units have different speeds. Some knowledge units can almost transfer freely in the knowledge because of the tiny sticky, some may not transfer smoothly and even the speed of it is near zero due to the strong viscous resistance. The speed of knowledge transfer in the knowledge field is expressed in u. According to the viscous fluid dynamics theory, the phenomenon of boundary layer will be produced near the surface of an object, when viscous fluid passes the surface of an object at a certain speed [46, 50]. Similarly, due to the stickiness of knowledge, it is believed that, when knowledge flow around an organization in the knowledge field, the phenomenon of the boundary layer will appear near the organizational boundary. The phenomenon of the boundary layer in the knowledge field is referred to as the boundary layer of knowledge field in this paper. As shown in Figure 1, the knowledge field is divided into two regions: the knowledge field inside the boundary layer and outside the boundary layer. The knowledge field inside the boundary layer is the area between the red solid line bl1 and bl2, and the other area is the knowledge field outside the boundary layer. Similar to the theory of fluid mechanics [51], the effect of stickiness on the knowledge field inside the boundary layer is so great that the velocity gradient of knowledge transfer is very large, and the velocity near the areas of the surface of an object (the object is M in Figure 1) tends to zero. That is, the effect of the stickiness of knowledge on knowledge transfer in boundary layer is significant, and the stickiness of knowledge inside boundary is not ignorable. However, the stickiness of knowledge outside the boundary layer is small, and even it can be ignored, it is approximatively considered that knowledge in the area is in the free-flow state without viscous force. It is known that with the value of knowledge increasing, the will of share becomes weak and the difficulty of knowledge transfer increases. Therefore, it is believed that the magnitude of the stickiness is directly related to the value of knowledge. In the current discussion, the knowledge in the knowledge field is divided into two categories according to its value or importance: sticky knowledge and general knowledge. Sticky knowledge is usually core and important knowledge for an organization, and general knowledge is not core knowledge and can be obtained freely, and its stickiness is small.

In the previous studies, there are arguments that knowledge field is rotational or not. Some researchers suggested knowledge field is rotational [23, 24, 52], and

others believed that knowledge field is irrotational or did not considered the rotation of knowledge field [22, 53]. According to viscous fluid mechanics, the area inside the boundary layer is the rotational area due to the stickiness of fluid in the flow process [54]. However, owing to the tiny viscous shear force, the rotation of flow field outside the boundary layer is negligible; namely, the area outside the boundary layer can be considered to be irrotational area [54]. Similarly, it is believed that knowledge field is rotatable owing to the knowledge stickiness. Due to the fact that the stickiness of knowledge outside boundary layer is small, the rotation of knowledge field outside boundary layer is small and even negligible. However, inside the boundary layer, the rotation of knowledge field is large because of the large stickiness of knowledge. That is, the knowledge field inside boundary layer is rotational, and the knowledge field outside boundary layer is irrotational. To clearly show this point, the microscopic subunit inside the boundary layer of knowledge is called knowledge element group (KEG) in this paper, as shown in Figure 1. In the microscopic subunit, there are interactions between different kinds of knowledge under the influence of strong viscous force. As the stickiness of each kind of knowledge in the knowledge element group is different, and the level and the direction of the viscous shear force on the different boundary of knowledge element group are also different, so the phenomenon of the rotation occurs under the action of viscous shear force. The six rotation situations caused by the viscous shear force with different levels and directions on the boundary of KEG are illustrated, as the marks a shown in Figure 1. Whereas, when the KEG is located outside boundary layer, the interactions between the different kinds of knowledge in KEG under the influence of viscous force is tiny, and the situation which is similar to the interaction between ideal inviscid gas molecules exists only in KEG. Meanwhile, the viscous shear force on the boundary of KEG is also tiny. Therefore, the rotation of knowledge field outside boundary layer is tiny and even negligible.

3 The dynamic model of knowledge transfer

The blunt body M on the x axis represents an organization in the knowledge field, which is the same as the Figure 1. In Figure 2, BC shows the boundary line of the boundary layer; represents the velocity of knowledge transfer in the boundary layer; H expresses the thickness of boundary layer at x=x0, and H1shows the thickness of boundary layer at x=x1. The variable dH shows that the variation of thickness when x changes the distance of dx.

The variables Fp, Fτ and Fe are the powers in the direction of x which represent the knowledge potential difference force, the viscous force and the extern driving force, respectively. The knowledge potential difference force, the viscous force and the extern driving force are caused by the knowledge potential difference, knowledge stickiness and the extent of the external driving, respectively. To analyse how sticky knowledge transfers under the interaction of internal and external force in the boundary layer, the dynamic model of sticky knowledge transfer is built, as shown Figure 2.

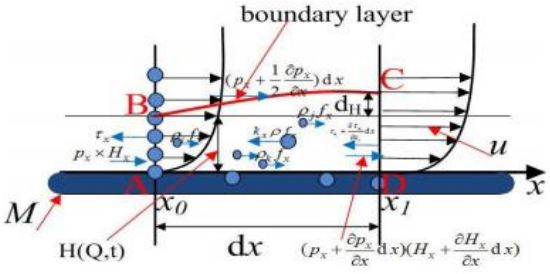

FIGURE 2 The dynamic model of knowledge transfer

Finally, to clearly describe the dynamic model of the boundary layer of knowledge field, the example of the supplier management of Japan's Toyota Motor Corporation is employed.

In the knowledge field, it is believed that the knowledge transfer in the boundary layer is mainly influenced by the three forces:

(i) Due to the difference of knowledge stocks among organizations, knowledge pressure (similar to water pressure and the voltage) is caused, and then the first field force, that is, the potential difference of knowledge force that lead to knowledge flow is generated [22, 56].

(ii) The influence of knowledge stickiness on knowledge transfer and sharing causes the second field force, namely the viscous force [36, 37].

(iii) The organizations within and outside the knowledge field, such as government and core enterprise, can make scientific incentive mechanisms to promote knowledge sharing and flowing.

Thus, the third field force is caused, which is referred as the external force [57, 58]. Under the joint action of the above three field forces, all kinds of knowledge unit in the knowledge field will move directionally.

The case of Japan's Toyota Motor Corporation is also introduced to discuss the sticky knowledge transfer in knowledge field. Japan's Toyota Motor Corporation (hereafter, referred to as simply Toyota) was founded in 1933, which is the biggest car company in Japan and world's top ten car companies, and it plays an important role in the world's auto industry. The success of Toyota to some extent comes from effective supplier management way. Toyota pioneered the management style of knowledge sharing among suppliers, which has had some great effects on supplier management, and has been adopted in many other companies. Toyota has always attached importance to its cooperation with suppliers, and it and 270 suppliers form a knowledge field by cooperation, in which the knowledge stocks of Toyota and its suppliers is significantly different, so there are the potential difference forces (Fp) prompting sticky knowledge transfer among Toyota and its suppliers. With the above force, Toyota would open and share sticky knowledge that can help suppliers improve productivity, and the suppliers also share their sticky knowledge with Toyota and others

so that suppliers and Toyota grow together through their mutual cooperation. Nevertheless, given their own interest consideration, suppliers are reluctant to share their core knowledge inside the boundary layer to others, so the transfer of the core knowledge in the knowledge field is hindered. The above core knowledge is called sticky knowledge, such as patents and core technologies. Generally speaking, the transfer of patents and core technologies is purchased at the expense of equal knowledge or cost of the users. The value of the equal knowledge or cost can be considered as the viscosity of the transferred knowledge. The force generated by sticky knowledge (Fτ) has the reverse force on the knowledge transfer.

Due to the viscous force, it is difficult to achieve sticky knowledge transfer smoothly in the knowledge field. Therefore, to be successful in implementing sticky knowledge transfer according to the wishes of the core organization (Toyota), some policies (Fe) should be introduced by Toyota to drive high efficiency knowledge transfer. For this, Toyota formulated two efficient governance mechanisms which is respectively reputation and commitment mechanism to make suppliers share their own core knowledge to others, as follows:

(i) During the process of cooperation, if the supplier positively shares the core or valuable knowledge (sticky knowledge) with others in the knowledge field, his reputation will be raised, and Toyota will offer more valuable technology or knowledge to him. Otherwise, if the supplier only obtains valuable knowledge from others in the knowledge field but is not reluctant to shares his own core knowledge or valuable knowledge (sticky knowledge), his reputation will be reduced, and Toyota will not offer key technology or knowledge to him and even break up the partnership.

(ii) Since the suppliers fear that their interests will be hurt when they share their core knowledge with others, Toyota establishes commitment mechanism to protect their interests.

This is, Toyota makes the commitment that the orders of the above suppliers will be increased and the supply prices will not be also raised due to their higher productivity within 2 to 3 years. Therefore, under the combined action of Fp, Fτ and Fe in the knowledge field, Toyota and its suppliers successfully achieve the goals of mutual cooperation, promotion and common development.

4 The conservation model of knowledge transfer

To describe the variation of knowledge stocks in the process of knowledge transfer in the boundary layer, the research object M is also employed, as shown in Figure 3.

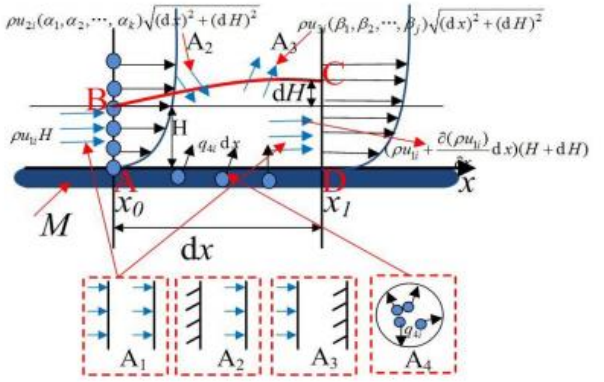

FIGURE 3 The conservation model of knowledge transfer

The blunt body M and BC represents an organization in the knowledge field and the outer horizon of the boundary layer, respectively; ui, H, H1 and dH represents the speed of knowledge transfer in the boundary layer, the thickness of boundary layer on the x0 points, the thickness of boundary layer on the x1point and the variation of thickness is caused as the point in the direction of x changes the distance of dx, respectively. The above is the same as the Figure 2.

In the boundary layer of knowledge field, the sticky knowledge of organizations do have is not to be constant, which flows constantly among organizations in the knowledge field. According to fluid dynamic theory, for a research object, generally speaking, if it has inflow variables, it also has outflow variables. Analogously, for the research object M in the boundary layer of knowledge field, the inflow variable on the boundary AB can be written as shown in Figure 3.

Unlike the flow dynamics, there are the other three ways due to knowledge specific attributes in the knowledge field, as the marks A2, A3 and A4 shown in Figure 3. From the mark A2, it has outflow variables but no inflow variables in the boundary layer. For example, when participating in the league and cooperation, the organization, in the knowledge field, shares its core knowledge (namely, the sticky knowledge) with others, but the spill over effect of the knowledge which is absorbed from others in the organization is not obvious because of the organization's low learning, low absorbing knowledge ability and low efficiency of utilizing knowledge gained from others. Thus, there might be a situation where the organization only shares core knowledge but not obtain valuable knowledge from the knowledge field. The process of knowledge transfer is achieved by overflowing the boundary of the boundary layer in the knowledge field. It should be mentioned that new knowledge will be created due to the novel combination of existing knowledge [61]. The extent to which actors can efficiently search for, access, transfer, absorb, and apply knowledge influences their ability to create knowledge [62, 63]. Another case is that new knowledge created by an organization itself is be stored in

the boundary layer and does not outflow the boundary layer, as the mark a4 shown in Figure 3.

As analysed above, we know that the variation of the thickness of boundary layer (the knowledge stocks of boundary layer) is characterized by the knowledge flow conservation equation in the boundary layer. The thickness of boundary layer of the knowledge field for each organization is dynamic, which changes with time and location. The factors, such as knowledge transfer between inside and outside boundary layer, knowledge creation, and usefulness of knowledge declining, can cause the variation of boundary layer thickness. Meanwhile, knowledge transfer should be in relative balance situation under the action of the function and mechanism in the boundary layer, and the mutual transformation process of "balance unbalance balance" promotes the updates and appreciation of knowledge.

5 Conclusions

The flow characteristics of viscous fluid are extended to the analogy analysis of the knowledge management in this paper. Some conclusions can be summarized as follows:

1) The contradictory relationship between knowledge stickiness and knowledge transfer in the knowledge management is illustrated based on the boundary layer theory in fluid mechanics. The boundary layer theory of knowledge field is put forward to analyse the stickiness and fluidity of knowledge, which extends the conception of knowledge field, and enriches the theory of knowledge management.

2) The boundary layer dynamic model of knowledge field based on the features of sticky knowledge transfer is constructed to discuss the dynamic mechanism of sticky knowledge transfer. The knowledge transfer conservation equation according to the law of conservation of knowledge stocks is built to further explore the updates and appreciation of knowledge in the transfer process of knowledge.

3) The thickness of boundary layer for each organization is dynamic. On the one hand, the features of knowledge, such as value, importance, specificity, and complexity, are constantly changing with the variety of time and the development the society, which changes the viscosity of knowledge and the thickness of boundary layer; on the other hand, there are knowledge transfers between inside the boundary layer and outside the boundary layer, knowledge creation and usefulness of knowledge declining in knowledge field, which can also make the thickness of boundary layer transformed.

4) The arguments about the rotation or not of knowledge field are explained through the boundary layer phenomenon of knowledge stickiness. It is believed that knowledge field is rotatable owing to the knowledge stickiness. Due to the fact that the stickiness of knowledge outside boundary layer is small, the rotation of knowledge field outside boundary layer is small and even negligible. However, inside the boundary layer, the rotation of knowledge field is large because of the large stickiness of knowledge. We can also maintain that, the knowledge field inside boundary layer is rotational, and the knowledge field outside boundary layer is irrotational.

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