Semiotic Interoperability
A Critical Step towards Systems Integration

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Abstract: Information systems integration becomes critical in enhancing organisational competitiveness through effective use of information resource provided by the whole host of information systems. Information systems integration in its nature is a process of bringing about the capability of communication and information exchange between systems; while interoperability, often as the result of systems integration, is such a capability. However currently there is a lack of theoretical foundation for representation and measure of the interoperability in organisations. Organisational semiotics provides a theoretical foundation for systems interoperability. A notion of 'semiotic interoperability' is proposed in this paper as a paradigm, guiding systems integration and measuring degree of interoperability, covering aspects from physical properties, transmission structure of signs, placing emphasis on communicating meaning, intention to social consequence of information.

1 INTRODUCTION

Information systems integration is becoming critical for organisation as enterprises seek to maximise their IT investment in order to support information sharing to become more agile and competitive (Clabby, 2003). The drivers for system integration often include both organisational and technical factors, such as the extended use of existing legacy systems often generates needs for integration with new systems; the need to consolidate and globalise especially in the circumstances of mergers and acquisitions where many legacy mission-critical systems need to be integrated to enhance information exchange; the seek for productivity increase as well as cost cut through integrating business processes, transactions and applications (Panian, 2006).

Therefore systems integration is not just connections among IT systems. It is the issues of the whole organisation where both social and technical aspects need to be considered. The information system integration is defined as the process that ensures the interactions between information systems necessary to achieve organisational objectives. The ideal integration of information systems should be organic and seamless communications among not only technical systems but also process, norms, people, culture as well as organisational strategies.

The nature of information systems integration lies in the successful signs communication among different systems. Semiotics, as the study of signs that examines the nature and properties of all kinds of signs (Morris, 1946; Peirce, 1931), provides the theoretical foundation on how signs can be successfully communicated among systems. Organisational semiotics is one of the branches of semiotics particularly related to business and organisations (Liu, 2000). Stamper has developed a semiotic framework which guides us in examining all the aspects of the signs and studying how signs are used for communication and coordination in an organisational context. Therefore organisational semiotics provides a solid theoretical foundation to guide the information systems integration. This paper will introduce a new concept of semiotics interoperability which is defined into different level of interoperability. Semiotic interoperability provides a solid conceptual framework by explaining how signs can be successfully communicated in different level. This can be further

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developed to guide the design of seamless integration as well as to assess organisation's integration level to identify organisation's requirement towards comprehensive integration.

2 INFORMATION SYSTEMS INTEGRATION AND INTEROPERABILITY

Information systems integration is the process that ensures the interaction between information systems necessary to achieve domain objectives (Chen et al., 2008a; EN/ISO I9439, 2003). The development of information systems integration can be divided into two phases: technical integration and comprehensive integration. Technical integration is the preliminary stage of integration which allows information systems to understand each other's functionalities in order to improve efficiency of using information (Chen et al., 2008b). In the context of computer-based systems, information system integration is the faculty for two heterogeneous computer systems to function jointly and exchange information resource. From a networked systems perspective, it gives the ability of interactions and information exchanges between information systems. Another point of view from (ISO, 2000) explains that two systems are considered as integrated if there is a detailed standard format for all constituent components. It improves the information exchange and utilisation interoperability between information systems, applications, devices and units (Guo and Wang, 2012).

Interoperability is the ability of information systems to share information, services, and functionalities among information systems (NEHTA, 2007). It can be measured to evaluate that the efficiency and productivity of information systems integration (Leite, 1998). The interoperability can be achieved through different levels and manners. From business and enterprise point of view, Panian (Panian, 2006) identifies interoperability through different types of integration which include data integration, business process integration, business activity monitoring and application integration. Chen and Vernadat (Chen and Vernadat, 2004) defines three levels from enterprise interoperability which covering physical level about interconnection of devices via computer networks; application level dealing with interoperability of software applications and database systems in heterogeneous computing environments; business level on coordination of functions that manage, control and monitor business processes.

Information systems integration can be seen as the process of sign communication not only among technical systems but also interactions in the social environment surround the systems. The effective and comprehensive information systems integration should fully consider and depends on the successful use of sign at different levels of communications, interactions and social activities. Organisational semiotics provides a sound theoretical foundation on how signs are used in the communications to support information systems integration in organisation. A new concept of semiotic interoperability is introduced in this paper which defines interoperability from a broader perspective of signs with the purpose of giving a theoretical guidance for effective information systems integration. Semiotic interoperability will look at information systems integration by explaining not only how signs are structured and used in language, how signs are organised and transmitted, what physical properties signs have, but also how signs function in communicating meanings and intentions, and what the social consequences are of the use of signs.

3 SEMIOTIC INTEROPERABILITY

3.1 Organisational Semiotics

Semiotics, as a branch of the philosophy related to linguistics, is the study of signs and symbols. It provides a sound theoretical foundation for understanding of the nature and characteristics of the sign-based communication. Organisational semiotics, as a sub-branch of semiotics particularly related to organisations, is the study of organisations using the concepts and methods of semiotics. Organisational semiotics provides a holistic view about signs, information, systems and organisations. An organisation can be seen as an information system where information is created, stored, and processed for communication and coordination and for achieving the organisational objectives.

3.2 Semiotic Framework

Stamper has developed a semiotic framework (Figure 1) that guides us in examining all the aspects of the signs and studying how signs are used for communication and coordination in an

organisational context. Organisations have both a technical and a social dimension and their performance relies heavily on their ability to integrate both of these dimensions. From this semiotic perspective, information systems integration is about how signs are used for successful communications in IT platforms serving technical business operations as well as human information functions supporting social dimension of business activities.

Table 1: Semiotic interoperability framework.

Social interoperability	The resultant interoperable systems should be coherent with the social commitment, obligation and norms in the organisation and support organisation's strategy, vision and objectives
Pragmatic interoperability	Processes supposed by the systems in individual contexts can be aggregated to achieve the overall intended purpose
Semantic interoperability	Ability of interpreting and converting information into equivalent meaning to allow information sharing between systems
Syntactic interoperability	Data exchange between systems through compatible formats and structures
Empiric interoperability	Sign transmission through compatible channels and protocols between systems
Physical interoperability	Connectivity between networks and hardware and devices

Physical world, as a separate branch concerned with the physical aspects of signs gives a handle to deal with the factors governing the economics of signs, which has become important in business contexts. Empirics, has been defined as another branch to study the statistical properties of signs when different physical media and devices are used. Syntactic, semantics and pragmatics respectively deal with the structures, meanings and usage of signs. Social world has been defined as the effects of the use of signs in human affairs.

The three upper layers in the framework are concerned with the use of signs, includes functions of signs in communicating meanings and intentions, and the social consequences while using signs. The three lower layers in the framework aim to answer questions on how signs are structured and used in language, how signs are organised, what physical properties signs have, etc. This work has been widely used in analysing business organisation and information systems design.

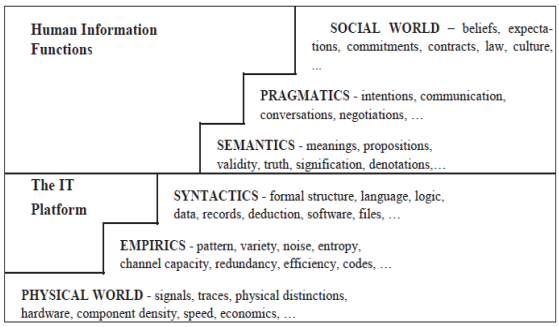

Figure 1: The semiotic framework (Stamper, 1973).

3.3 Semiotic Interoperability

It is common-sensible to see information systems integration as a process of sign communication. The semiotic framework that explains all aspects of how signs can be used and communicated for successful communication, determines the level of interoperability of information systems integration. Therefore we say systems are integrated in certain level of interoperability if signs among systems are successfully communicated in certain semiotic framework level.

Our previous research work (Li, 2010) proposes a set of theoretical and methodological methods for information systems integration in digital hospital. The theory of organisational semiotics has been used for developing a list of methods (e.g. modelling methods, implementation methods) and models (e.g. ontology model, activity model). In addition, a theoretical and conceptual architecture has been proposed based on the semiotic framework. This architecture identifies the requirements for information systems integration at several levels (i.e. organisational goal level, business services level, business activities level, system functions level, system communication level, and infrastructure level), which support the communication among information systems. Li's work elaborates the application of organisational semiotics theories, and reveals that the semiotic framework is able to illustrate the operation of organisation as an information system, and to guide successful communication between information systems. Hence we focus on interoperability and communication in this paper and propose the concept of semiotic interoperability to identify the level of system integration based on semiotics framework (Filipe, 2000; Liu, 2000; Stamper, 1973) and previous work on how organisational semiotics supporting

information systems integration (Li, 2010).

Semiotic Interoperability allows information systems to work together through communication with insight into the physical properties, transmission structure of signs, placing emphasis on communicating meaning, intention and social consequence of information. Semiotic interoperability can be further explained by the semiotic interoperability framework (Table 1):

• *Physical interoperability*

The interoperability at physical level indicates that connectivity between networks, hardware and devices. This level is concerned with the physical connection and transmission channel in sign communication. Signs are modelled by physical signals (varying in time) and marks (static in time), their sources and destinations and the routes over which they are transmitted. Physical interoperability is achieved when a chain of physical tokens, transmitted along a route, is received at the other end, by the receiver, conserving the same physical properties. For example, the hardware devices of the systems must be interconnected in order to support the data transmission. However, although the physical level has been achieved, the data transmission cannot be succeeded without proper communication channel and protocols. These issues are concerned at empiric interoperability.

• *Empirics Interoperability*

Empirics interoperability ensures sign transmission through compatible channels and protocols between systems. This level is concerned with the matching of coding and decoding between sign sender and receiver based on statistical properties of information. In such communication, coding is done at the sending end and decoding at the receiving end. Interoperability at this level is achieved when the receiver can reconstitute the same sequence of symbols that were sent by the sender, irrespective of any problems at the physical level. Research at this level involves the study of communication devices that are well matched to the statistical characteristics of the media. The word meaning/matching in this level means the equivalence of codes. The empiric level ensures the capacity of communication channels and protocols of different information systems are matched. For example, specific bandwidth and proper communication protocols such as IEEE 108.11g have to be matched for both systems in order to successfully transmit the data. However, the information exchange still may fail if the structures of the data for information systems are incompatible. The issue of data structure is concerned at the syntactic level.

• *Syntactic Interoperability*

Syntactic interoperability ensures data exchange between systems through compatible formats and structures. Syntactics is concerned with rules of composing complex signs from simple ones. Communication is successful if the devices are able to identify and internally rebuild each other's symbols and expressions, irrespective of the symbols that are used. The syntactic interoperability is achieved when the expression of information, or language, or formula can be recognised by different information systems. The data structures and format of file and message have to be readable to both ends of communication. For example, a program wrote in JAVA cannot be recognised by other non-JAVA supported information systems. However, although the syntactic level is achieved, the communication still may fail if the message cannot be understood by other information systems. These issues are concerned at the semantic level.

• *Semantic Interoperability*

Interoperability at semantic level indicates the ability of interpreting and converting information into equivalent meaning to allow information sharing between systems. Semantic level is concerned with the meaning of signs. At the semantic level of use of language, meaning acts as the operational link between signs and practical affairs. People use signs or a language in communication. To enable one person to understand another, there must be some principles governing the use of signs which are established and shared in a language community. At the semantics level, communication is successful if signs are interpreted for both sender and receiver according to same principles. If an utterance may be interpreted in several different ways this means that the interpretation selected by the speaker would be the same one selected by the hearer. The semantic interoperability requires that the content's meaning and governing norms can be shared for different information systems. The semantic level addresses the issue of semantic interoperability, and involves terminology aspects (homonyms, synonyms, scope) as well as human language aspects. The semantic interoperability can be achieved to give the same meaning to exchanged information between information systems, and it requires a conceptual model which describes what information is exchanged in terms of concepts, properties, and relationships between these concepts.

• *Pragmatics Interoperability*

Pragmatics interoperability ensures that processes supposed by the systems in individual contexts can be aggregated to achieve the overall intended purpose. Pragmatics is the level of semiotics concerned with the relationship between signs and the potential behaviour/intention of responsible agents, in a social context. Therefore, successful communication at this level is achieved if the hearer understands the speaker's intentions, irrespective of the semantic interpretation of the communicative act. The communication may be successful even if the hearer does not do what the speaker wishes him to do, as long as the hearer correctly interprets the intention expressed by the speaker

Interoperability is achieved at this level when processes serving different purposes under different contexts by different information systems can be composed to jointly support a common intention. The emphasis is on the context awareness for processes integration. The following elements can be considered in the context: information system itself, intention, purpose, theme, time, location etc.

• *Social Interoperability*

Social interoperability ensures that the resultant interoperable systems should be coherent with the social commitment, obligation and norms in the organisation and support organisation's strategy, vision and objectives. Communication at the social level requires the hearer and the speaker to share social norms. A sign is meaningful if it actually alters those norm structures. Knowledge at the social level is thus essentially defined in terms of norms, i.e. regularities of behaviour, perception, and judgement. The interoperability in social level ensures the intention or purpose of the sender has led to a social consequence to the receiver through the resultant interoperable systems. Social commitments and obligations can often be created or discharged as the result of a conversation. Even if the hearer does not do apparently anything, the communication succeeds at the social level as long as a result of the communicative act, any social commitments are created or modified.

The semiotic interoperability illustrates how well the information systems are integrated. They also identify requirements to be improved at each level. Each level is correlated but independent with its neighbours. The integration has to achieve the lower semiotic interoperability level before moving upwards. For example, the integration at the physical level has to be achieved with right hardware and right components before it is achieved at the empiric level. Otherwise, even though the information systems have been provided with the right protocol and right communication channel, they still cannot be successfully integrated without right selections of hardware and components. Similarly, the interoperability of syntax at syntactic level is essential for information systems to understand the meaning of exchanged information.

4 DISCUSSION AND CONCLUSIONS

Currently information systems integration becomes critical for organisations to enhance competitiveness through information sharing and maximising their IT investment. The issues on systems interoperability and how interoperable systems need to be as a strong support for organisational competitiveness have drawn many attentions of researcher.

More and more researchers realise that it is important to consider interoperability from not only technical aspects but also higher level of communication in human and social activities. Some interoperability evaluation frameworks have been proposed but there is a lack of solid theoretical foundation leading to a sufficient coverage to define and evaluate interoperability as well as guide the integration through effective sign communication across technical platform and human information interactions. Most of the current interoperability only covers physical, empirics, syntactics and semantics interoperability, such as LCIM (Tolk and Muguira, 2003), e-Health IF (NEHTA, 2007), Enterprise IF (Chen and Daclin, 2006) and i-Score (Ford and Colombi, 2007). Some of the researches have mentioned interoperability from pragmatic or social level such as EIF (EIF, 2004), AIF (ATHENA, 2003; Berre et al., 2007) and QIAM (Fewell et al., 2004), but the above still remain inadequate because currently there is no framework for a fundamental representation of interoperability through a comprehensive aspects of successful sign communication.

The semiotic interoperability provides a theoretical concept covering how signs are communicated successfully from physical to social level in order to achieve effective information systems integration. Although the concept and framework of semiotic interoperability is new, some of the constituent claims have been studied in our previous researches on how semiotics supports information systems integration (Li, 2010; Li et al., 2013, Li et al., 2009).

Based on the concept of semiotic interoperability, our future work will develop a detailed semiotics interoperability evaluation framework to assess and diagnose interoperability of information systems in an organisation. This evaluation framework will be used to identify organisation's system integration requirement with an aim to guide effective system integration supporting organisational objectives.

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