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Assessing Pragmatic Interoperability of Information Systems from a Semiotic Perspective

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Abstract. Most of studies on interoperability of systems integration focus on technical and semantic levels, but hardly extend investigations on pragmatic level. Our past work has addressed pragmatic interoperability, which is concerned with the relationship between signs and the potential behaviour and intention of responsible agents. We also define the pragmatic interoperability as a level concerning with the aggregation and optimisation of various business processes for achieving intended purposes of different information systems. This paper, as the extension of our previous research, is to propose an assessment method for measuring pragmatic interoperability of information systems. We firstly propose interoperability analysis framework, which is based on the concept of semiosis. We then develop pragmatic interoperability assessment process from two dimensions including six aspects (informal, formal, technical, substantive, communication, and control). We finally illustrate the assessment process in an example.

Keywords. Pragmatics, Pragmatic Interoperability, Semiotic Interoperability, Systems Integration

1 Introduction

In the study of the interoperability, most of the work focuses on discussion at a technical level. Although some of them have extended to deal with semantics, a very limited number of publications elaborate the interoperability at the pragmatic level [1]. Undoubtedly the research on technical and semantic interoperability can help establish a better understanding of data exchange and data interpretation, as well as leading to the development of supporting technologies and standards. However, the integration requires assessment of pragmatic interoperability that ensures supported process can act upon the semantic information in order to deal with the complexity. The pragmatic interoperability is concerned with the relationship between signs and the potential behaviour and intention of responsible agents. Our past work defines the pragmatic interoperability as a level concerning with the aggregation and optimisation of various business processes for achieving intended purposes of different information systems. This paper, as the extension of our previous research [1], [2], is to propose an assessment method for measuring pragmatic interoperability of information

systems. We firstly propose interoperability analysis framework, which is based on the concept of semiosis. We then develop pragmatic interoperability assessment process from two dimensions including six aspects (informal, formal, technical, substantive, communication, and control). We finally illustrate the assessment process in an example. The next section briefs the concept of semiotic interoperability and pragmatic interoperability. Section 3 proposes the pragmatic interoperability analysis framework, and section 4 elaborates the assessment model for measuring pragmatic interoperability. The paper ends with a discussion of future work.

2 Background

Before defining pragmatic interoperability, our previous work has discussed the concept of semiotic interoperability [2], applied the concept of pragmatic interoperability in healthcare domain for analysing interoperability of systems integration at radiology department. The semiotic framework [4]–[6] 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 at a certain interoperability level if signs among systems are successfully communicated at a certain semiotic framework level. Our previous works [1], [2] have proposed the concept of semiotic interoperability. The semiotic interoperability allows information systems to work together through communication with insight into six levels: physical, empirical, syntactical, semantic, pragmatic, and social. In addition to our definition of pragmatic interoperability, other researchers have contributed in pragmatic interoperability. Benson [7] defines it as coordination of work processes across different people to enabling work collaboration. Sadeghi et al. [8] state the pragmatic interoperability in healthcare is the ability among healthcare processes and various actors (i.e. healthcare providers and patients) that interact with information systems. We address systems interaction from the perspective of semiotic interoperability, especially at pragmatic level, which is concerned with the relationship between signs and the potential behaviour and intention of responsible agents. We define the pragmatic interoperability as a level concerning with the aggregation and optimisation of various business processes, in order to achieve intended purposes of different information systems. It is also concerned with the relationship between signs and the potential behaviour/intention of responsible agents, in a social context. Within a social community, there exist common knowledge and shared assumptions. These basic assumptions serve as a minimum basis for communication. Therefore, successful communication at this level is achieved if the hearer understands the speaker's intentions, which goes beyond the semantic interpretation of the communicative act. 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 the context awareness for processes integration. The following elements can be considered in the context: information system itself, intention, purpose, theme, time, location etc.

3 Pragmatic Interoperability Analysis Framework

Before assessing the pragmatic interoperability, our past work has developed an interoperability analysis process that pre-investigates the key factors (e.g. requirement, integration approach, interoperability measurement, knowledge foundation) of pragmatic interoperability. Based on findings of the investigation, we combine them with the semiosis concept [5] to develop an pragmatic interoperability analysis framework as shown below.

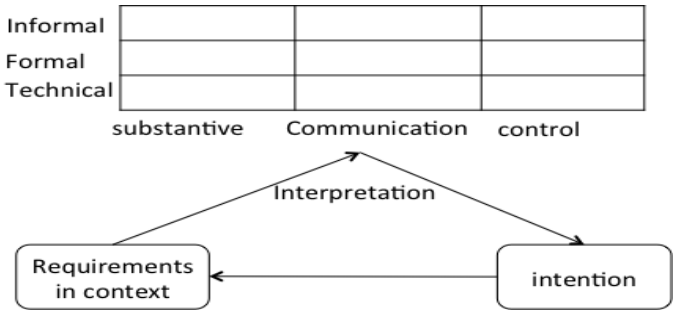

Fig. 1 Pragmatic Interoperability Analysis Framework

The development of the interoperability analysis framework is based on the concept of semiosis. Semiosis is the central concept of semiotics [5], it is a process of understanding involving transformation of signs. As a sign-mediated process, it gives meanings for understanding an object or actuality. It is also applicable to any type of sign-processing activities e.g. information systems integration. The interpretation is subjective and depending on the viewpoints of the interpretant or context. In the context of information systems integration, the context itself and its information systems are complex, artificial, and purposefully designed. They require integrated features as well as alignments between the business processes and the system functions. In order to assess and measure the pragmatic interoperability, our developed pragmatic interoperability analysis framework starts with articulating requirements in context such as interoperability environment, stakeholders, motivations, constraints, and locations. Secondly, the interpretation process assesses interoperability from two dimensions including six aspects (informal, formal, technical, substantive, communication, and control), which will be elaborated in next chapter. Thirdly, the interpretation process will help to indicate whether the requirements have been met to achieved the intentions e.g. business goals, responsibilities, and constraints.

Requirements articulation defines the problem space in which the requirements for interoperability are contextualised. Specifically it includes the identification of goals, tasks, problems, and opportunities that defines interoperation requirement in the context of organisation [9], [10]. Barriers at the informal level e.g. resources reallocation, political issue, privacy and security, people issues, culture change, and behavioural patterns are most widely highlighted in relevant researches [11]–[15]. Issues at formal level such as information flow, cross-functional integration are also discussed [11], [16]–[19]. Most interoperability requirements are articulated to

overcome the interoperability barriers and realise the opportunities in organisations. Panetto and Molina [20] analyse and characterise several research challenges for Enterprise Integration and Interoperability. Their results are elaborated by a more intensive summary and contributions highlighted [21]. The challenges are classified from four dimensions (business, knowledge, applications and communications) where challenges of interoperability in enterprise are identified to include model interoperability, process interoperability and business information integration, etc. Therefore interoperability requirement can also be identified by combining conceptual, organisational and technological barriers with business, process and data concerns [22]. The integration can be also also seen as a methodological process to measuring the gap between desired interoperability goal and actual status of the system, and to adjust both the goal and interoperation actions if necessary. The step of assessment and measurement process are elaborated in next section.

4 Pragmatic Interoperability Assessment Process

The nature of information systems interoperation relies on successful signs communication [2], and each information system analysis and design must start with understanding and modelling the organisation where information system exists [5]. The organisation onion [6] stresses the distinctions as well as the interdependent links between the business process and IT systems. The organisation morphology provides a useful modelling method for understandings the norm structure of information system. Each information system can be characterised as a structure of norms that allow functions can be coordinated for certain purposes [5], and pragmatic interoperability, is to enable the purposes of each information system can be understood and perceived during interoperation, so the business processes can be aggregated accordingly. Therefore, measuring pragmatic interoperability between information systems is to measure the interoperability of norms that drive the business processes. Hence, we develop a measurement model that assesses the pragmatic interoperability from two dimensions (i.e. organisational onion, organisational morphology). The measurement model is the core of the whole assessment process. Before elaborating the model, the whole assessment process illustrates different stages and steps for measuring pragmatic interoperability as shown below:

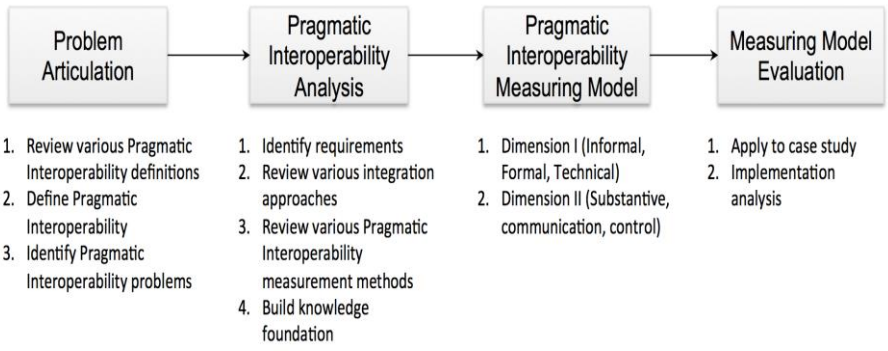

Figure 2 Pragmatic Interoperability Assessment Process

The pragmatic interoperability assessment process starts with problem articulation. This stage defines the problem spaces of pragmatic interoperability and articulates relevant integration requirements in specific context. Various pragmatic interoperability definitions are reviewed for identifying problems. After identifying the problems, the next stage is pragmatic interoperability analysis. It identifies pragmatic interoperability requirements, and reviews various integration approaches and interoperability measurements at pragmatic level. The next stage is pragmatic interoperability measurement model, which is the core of the whole process. The model aims to measure the pragmatic interoperability from two dimensions including six aspects (formal, informal, technical, substantive, communication, and control). The last stage is to evaluate the measurement model by applying it to case study.

4.1 Pragmatic Interoperability Measurement Model

The measurement model has two dimensions. Each dimension has three perspectives as displayed in the Figure below: 1) informal layer, 2) formal layer, and 3) technical layer for organisational onion; and 1) substantive area, 2) communication area, and 3) control area for organisation morphology.

Informal			
Formal			
Technical			
	Substantive	Communication	Control

Fig. 3 Pragmatic Interoperability Measurement Model

In system integration, the organisational onion illustrates on how an integrated system works, and the organisation morphology helps classify different norms that drive business processes. In pragmatic manner, the norms are regularities of perception,

behaviour, belief and value that are exhibited as customs, habits, patterns of behaviour and other cultural artefacts. The developed measurement model combines both and provides coherent guideline for indicating key perspectives of measuring interoperability.

Dimension I

- Substantive

Business process and technical functions as well as cultural aspects are driven by norms in information system integration. The substantive norms are productivity-related and directly contribute to the aim and objectives. The pragmatic interoperability in this manner is to aggregate different substantive norms in order to achieve intended goal(s). For example, in healthcare environment, the substantive norms are direct actions and orders among different information systems. Key actions such as order entry, and patient report generation, are typical substantive norms. Those could be aggregated based on the intended goals.

- Communication

The communication norms are interaction-related. They coordinate relevant people, procedures, business functions, and supported systems for undertaking substantive norms. Those communications are required to coordinate the temporal and spatial use of resources for substantive activities. Typical examples are communications by sending memoranda, announcements of meeting and events, telephones and emails. The pragmatic interoperability is to integrate different communication norms in order to eliminate the redundancy and improve communication efficiency. For example, in healthcare environment, message sending and receiving, communications between clinicians and nurses, and emergency interactions are where communication norms exist, and can be integrated for intended coordination.

- Control

The control norms are execution-related. They aim at reinforcing the whole business system running properly, particular the substantive and communication norms. Monitoring and evaluating are the main techniques of control norms. Typical examples are inter-firm agreements or contacts between organizations. The pragmatic interoperability is to ensure that the control norms function as required but consumes less, so the power of reinforcement will remain but the cost will not be increased. For example, in healthcare environment, the control norms should be regulations that reinforce the substantive and communication norms perform correctly.

Dimension II

- Informal

In informal level, culture aspect plays an important role. This aspect can be expanded as beliefs, habits and behaviour patterns of individuals. In this manner, the pragmatic interoperability is to align different culture aspects and solve conflicts of cohesiveness. An integrated information system would support perceiving of personal beliefs and organisational ground rules, whereas an un-integrated information system may be considerable conflicts between the organisational level and personal level. Issues like restriction to staff behaviour (more significant benefits from systems integration), information collaboration (information channels alignment), varieties of purchased information systems (different venders and services providers), and privacy and security concerns should be solved in this level. For example, in healthcare environment, the informal level is to concern with the understanding of the

healthcare, regulatory, legislative and enterprise environment in which information systems need to be deployed to support healthcare delivery. It requires agreement on key organisational concepts such as policies, processes and roles; it also captures relevant patterns such as compliance, governance, legislative and change management.

- Formal

In formal level, business functions and procedures play dominant role that specifies on how functions should be carried out and how tasks should be performed. The pragmatic interoperability is to align procedures and rules in order to achieve higher efficiency. It defines business goals, model business processes and brings the collaboration of administrations what aim to exchange information and have different internal structures and processes. Besides, it also addresses the requirements of the user community by making services available, accessible, identifiable and user-oriented. Issues like policy (integration cuts across political boundaries), and procedure (integration causes process and operation changes) should be solved in this level. It supports seamless sharing of information, which is universal interpretation of information through data processing based on cooperating applications. For example, in healthcare environment, it is concerned with representations and interpretations of clinical, administrative and statistical information. It requires agreement on a core set of information concepts, such as information system itself and the relationships between information systems, as well as its clinical functions; it also captures relevant patterns such as quality of information and application scope.

- Technical

The technical level mostly refers to the technical computer systems and their technical functions. The systems and functions can be programmed according to norms and procedures. The pragmatic interoperability is to align technical functions and business processes in order to achieve higher system productivity. It supports seamless sharing of data, which is automated sharing of data between information systems based on a common exchange model. It also covers the technical issues of linking computer systems and services. A few key aspects are included such as interconnection services, data integration, open interface, data presentation and exchange, and accessibility will be dealt with in this level. For example, in healthcare environment, it is concerned with the understanding of technical functionality for supporting information systems. It requires agreement on a core set of technical concepts, such as technical components and devices, the interactions between components, interface and technical services; it also captures relevant patterns such as technical architecture styles and styles of component interactions.

4.2 Agent-Based Process Decomposition and Aggregation

Our developed model measuring pragmatic interoperability from 2 dimensions. Dimension 1 contains 3 aspects (substantive, communication, control), and dimension 2 contains 3 levels (informal, formal, and technical). The example of agent-based process decomposition and aggregation illustrated in figure below provides a picture of how processes are integrated in pragmatic level. The concept of Pragmatic Frame is adopted for storing pragmatic information, mainly the purpose and context of each

process abstract [23]. The process can be decomposed into several sub-processes and each sub-process has its own context, purpose and semantic definition. Each process is also a set of activities, and the activity abstract contains the basic functions and pragmatic information of the process.

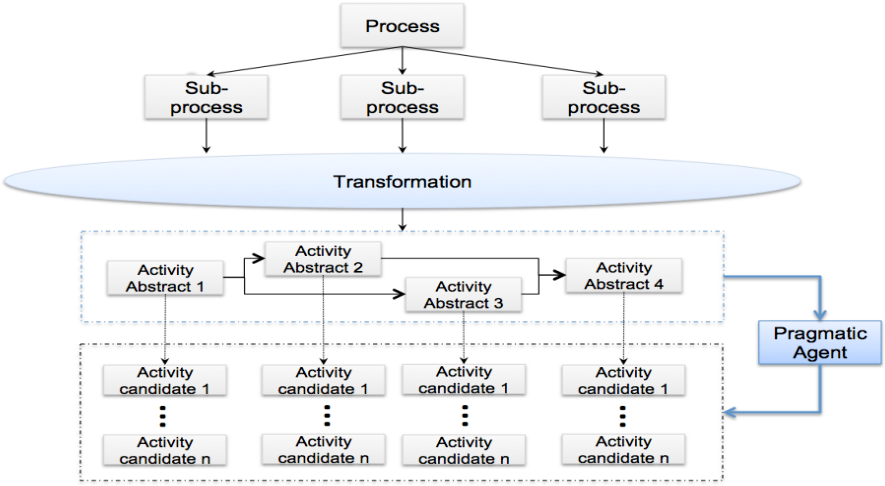

Fig. 4 Pragmatic process decomposition

After the process has been captured, it will be parsed into semantic terms that represent the meaning of the process. Each sub-process has been annotated with the semantic description and the goal to describe the detail of a list of expected activity candidates. The decomposition stage is to identify purposes for their aggregation in the next stage. The pragmatic agent uses the abstract to search the relevant activity candidates. The abstract contains semantic information, which can be searched by the agent. Finally only one candidate will succeed and be selected.

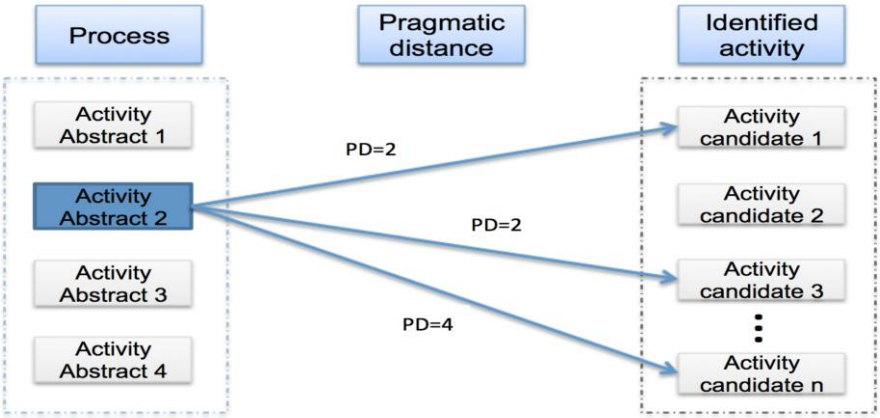

Fig. 5 Candidate selection by pragmatic distance

Each sub-process and its activities have various contexts for different purposes, and those contexts and purposes are defined based on policy designed. The activity works perfectly with its own context, but not all the activities works within their own contexts. The pragmatic ranking mechanism matches the related context (expected activity candidates) and find out the closest solution by calculating their pragmatic distance [23]. The ranking list is produced for each activity abstract and its candidates (displayed in Fig. 5).

5 Conclusion and Future Work

This paper is the extension of our previous research. It proposed an assessment method for measuring pragmatic interoperability of information systems. The developed interoperability analysis framework is based on the concept of semiosis, and contains three phrases (requirement in context, assessment model, and intentions). The developed assessment model measures pragmatic interoperability from two dimensions including six aspects (informal, formal, technical, substantive, communication, and control). The pragmatic interoperability at informal level is to align different culture aspects and solve conflicts of cohesiveness; to define business goals, model business process, and align procedures and rules in order to achieve higher efficiency at formal level; to align technical functions and business process in order to achieve higher system productivity at technical level. The substantive norms are productivity-related and directly contribute to the aim and objectives; the communication norms are interaction-related and coordinate relevant people, procedures, business functions, and supported systems for undertaking substantive norms; the control norms are execution-related and aim at reinforcing the whole business system running properly, particular the substantive and communication norms. The future work will focus on validations of the proposed assessment process.

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