Foundations and Research Trends In Object-oriented Information Systems

Shushma Patel

This chapter focuses on information systems and in particular research trends in Object-oriented Information Systems and Business Information Technology. The paper outlines the foundations of Object-oriented Information Systems and Business Information Technology. The domain of Object Oriented Information Systems is analysed and a generic structure of OOIS as a branch of computer science is derived. The domain of Business Information Technology is analysed and presented within the context of the Business and Information Systems. It defines both information and information systems from computing and business perspectives and shows how current information systems fit into this area. This paper looks at the foundations and research trends in these multi-disciplinary areas.

Introduction

It is an accepted fact that the term software engineering has been around since the advent of the first computer. Over the past three decades there has been a large body of knowledge that contributes towards the discipline of software engineering. The early definition of software engineering was first proposed in the late sixties by Bauer (Naur and Randell, 1969) at a NATO-sponsored conference. The definition takes a developer's view of producing and managing the software production process, with scant regard for the impact of the software on the environment.

In the late 1980s the application of computing shifted from the scientific domain to the business domain as a result of the improvement of the hardware and software technologies. This shift resulted in applying the technology to solve routine business problems. The building of business software entailed developing new conceptual tools to enable business analysts to capture the essential information requirements of an organisation. Since the 1980s a large amount of knowledge has been accumulated within the discipline of information systems. In the following sections, we discuss the evolution of Business Information Technology and the problems of delivering robust systems.

What is an Information System?

Wang et al. (1998) clearly trace the history and the philosophical foundations underpinning the discipline of information systems for a computing perspective.
Outlined below is a summary of the findings.

The original work in the area of information theory is attributed to Shannon during 1948-49 (Shannon, 1948, 1949). However, Bell and Goldman first used the term information in 1953 (Bell, 1953; Goldman, 1953). The term information was defined as a probabilistic measure of the quantity of message that can be obtained from a message source and is based upon Shannon’s information theory.

Traditionally, the classical information theory has been based on communications, signals analysis and coding theories. However, in the domain of modern applied computer science and in the software and information technology industries, the term information has a much more practical and concrete meaning that focuses on data and message presentation, storage and processing. With this orientation, information is regarded as an entity of messages, rather than a measurement or metric of messages in the classical information theory. Based upon this view, a definition of information and information systems can be derived, as shown below:

**Definition 1.** Information is a set of organised data that represents messages, knowledge and/or abstract real-world entities. With the above definition of information, an information system can be described as a system which manipulates information as shown below:

**Definition 2.** An information system is a computer-based system for collecting, storing, processing (adding, deleting, updating), producing, presenting, searching and/or retrieving information.

It is worth noting that the latter definition is a broad implication of the concept of an information system, rather than the conventional implication on database systems only. For instance, with this definition, an advanced word processing system in a PC can be regarded as a typical personal information system.

To appreciate the difficulties of engineering information systems one must understand the philosophical foundations of this discipline. Wang et al. (1998) compared the nature of information systems with other science and engineering disciplines and found a number of interesting fundamental differences. The key elements of information systems, namely Information, Accumulation of Information and Virtualisation, were analysed. The comparisons are outlined below.

**Information vs matter:** Human knowledge about the world can be categorised into two systems: concrete and abstract worlds. Matter or natural entities form the first; and the latter is represented by information – the human abstraction of the real world. From this perspective, our world exists in two basic forms: information and matter. Therefore information science and technology are fundamental branches of science in the human knowledge structure, which study theories and methodologies of information processing.

**Accumulation of information vs conservation of matter:** According to the natural law of conservation, matter can neither be reproduced nor destroyed. However, in contrast, important attributes of information are that it can be reproduced, destroyed and accumulated. The accumulation of information is the most significant attribute of information that human beings rely on for evolution.
Virtualisation vs realisation: In conventional manufacturing engineering, the common approach moves from abstract to concrete and the final product is the physical realisation of an abstract design. However, in information systems engineering, the approach is reversed. It moves from concrete to abstract. The final software, database and knowledge base are the virtualisation (coding) and invisibility of an original design, which describes the real-world problems. The only tangible part of an information system is the storage media or its run-time behaviours. This is a unique feature of information system engineering.

What is an Information System?

The term ‘business’ denotes an organisation that is involved in trading. Trading is the exchange of one thing for another. Running a business includes purchasing and selling products or services. The customer or receiver of the product/service pays a price to the supplier of the product/service. One of the main goals in business is to maximise profit. The profit is the amount of net gain derived from trading. This explanation of the term business is the bare minimum. In reality it is much more complicated than this.

Running a business has become extremely complex. There are many issues, concepts and variables involved in understanding and efficiently running a business. These require better tools and techniques with which to manage and run the business and help the business work effectively, efficiently and productively. Building information systems has been seen to be one of the solutions to some of the business problems. It can also be used for improving the running of the business.

A working definition of information systems and its component parts such as systems, data, information and knowledge is provided below:

Definition 3. A system is a set or arrangement of elements that are organised to accomplish some predefined goal.

Within the context of the business domain definitions 1 and 2 are valid; however, we need to extend these definition as shown below:

Definition 4. Information is a set of organised data that represents messages, knowledge and/or abstract real-world entities and it has a value to the stakeholder in a specific content.

Definition 5. An information system is a set or collection of collaborating resources (e.g. hardware, software, people, database, documentation, etc.) organised for the goal of storing, browsing, accessing, retrieving, handling, manipulating and processing data to provide information to the stakeholders.

In coming to the above definitions, we have defined data as:

Definition 6. Data is a representation of things that are known such as names, dates, quantities etc. that can be captured, stored, retrieved and transmitted. Data can be precise or judgemental. Also data has a price and can be sold, lost or stolen.

To extend the perception of information systems within the context of the business domain, we need to look at the purpose of information and information systems and
how they are used for the benefit of the business. Both the amassing of information and its constructive utilisation results in knowledge. Therefore we can define knowledge as:

**Definition 7.** Knowledge is the sum of what is known, a state or condition of understanding. Knowledge is the aggregate of the information held with understanding.

**What is Business Information Technology?**

The use of computers in complex organisations has changed in that manipulation of knowledge and information are undertaken as cooperative activities (Smørdal, 2000). In information systems development the concept of artefact mediation is interesting. The computer is an artefact that can mediate several aspects of activity. Based upon this, activity theory postulates that the nature of any artefact can only be understood within the context of human activity, i.e. by identifying the ways in which this artefact is used by people, the purpose it serves and its developmental history (Smørdal, 2000; Kaptelinin, 1996).

The software engineering and the information systems perspectives focus on the problem of developing systems for a given problem domain. Therefore, in traditional computing the purpose of the computer system is to handle, control or monitor. The discipline of Business Information Technology, however, extends the software engineering and information systems disciplines by focusing on both the problem and the application domains. Therefore, the application domain takes a broader view of the role of the computer system (the artefact) and how it is used within the organisational context (Mathiassen et al., 1993). The emphasis is placed on the integration of the real world and the computer world.

Business Information Technology is not merely the integration of people, technology and organisational structures, but also how all of these can be utilised as a knowledge resource for the benefit of the organisation. Therefore, the integration of definitions 5 and 7 defines the discipline of Business Information Technology.

**Fundamentals of Object-Oriention**

Although object-orientation (OO) is one of the broadly used concepts in computing and information systems, the literature presents few clear and unified definitions of OO. In this section we trace the history of object-orientation, describe the implication of object and OO, analyse the extension of the concept and categorise the technologies for OO. We define the discipline of Object-oriented Information Systems (OOIS) and review the research reported in OOIS’ 94-03 (Patel et al., 1994; Murphy et al., 1995; Patel et al., 1996; Orlowska et al., 1997; Rolland et al., 1998; Patel et al., 2000; Wang et al., 2001; Bellahsene et al., 2002; Konstantas et al., 2003), a generic structure of OOIS is derived, and trends in OOIS are analysed.

**What is object-orientation?** To enable the question of what is object and object-orientation to be answered, one needs to address the following issues: what is the implication of OO? What is the intention and extension of OO? Tracing back the
history of programming methodologies, it can be concluded that object-orientation is a natural extension and combination of two mainstream programming approaches: functional-oriented and data-oriented programming. Therefore, the definition of object-orientation can be based on the concept of object in programming and system design. An object is defined as an abstract model of a real-world entity and/or a computational module that is packaged by an integrated structure of interface and implementation, and is described by methods for its functions and by data structures for its attributes.

Object-oriented technologies were originally designed for programming. Therefore, OO was initially an implementation tool rather than a design tool. However, as OO programming became broadly accepted, it was found that OO technologies could be used not only in programming, but also in design and analysis. OO technologies are fairly generic and are applicable in almost every phase of the software development life cycle. Based on this view, object-orientation can be defined as a type of system design, analysis and/or implementation approach which supports an integrated approach to software development.

**Basic attributes and classification of OO technologies.** The fundamental attributes, which can be commonly identified in OO technologies, are encapsulation, inheritance, reusability and polymorphism. Within this set of basic attributes, encapsulation is a direct representation of the fundamental concept of abstraction, information hiding and modularisation in objects; inheritance and reusability are powerful features for improving productivity and quality in software and system development; and polymorphism is a supplement of flexibility to the other attributes of OO.

In viewing OO technologies as generic system analysis, design, implementation and reengineering approaches, a classification of existing OO approaches can be presented as in Table 11.1.
Table 11.1. Classifications of object-oriented methodologies

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<th>OO Category</th>
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Object-oriented information systems. Based on the discussion of the implications of business information technology, the analysis of the nature of information and the formal description of object and object-orientation, an OOIS can be defined thus: An OOIS is an information system which employs object-oriented technologies in system design, analysis and/or implementation.

This definition indicates that an information system can be classified as an OOIS if its analysis, design, implementation and testing adopt object-oriented technologies.

An overview of OOIS research and trends. A review of the subject areas in the past events of OOIS’ 94-03 (Patel et al., 1994; Murphy et. al., 1995; Patel et al., 1996; Orlowska et al., 1997; Rolland et al., 1998; Patel et al., 2000; Wang et al., 2001; Bellahsene et al., 2002; Konstantas et al., 2003) has identified that the domain of OOIS has covered a wide range of areas, such as hardware, software, people, organisational infrastructure, networking, communications, processes, incoming data, outgoing data, and other resources.

Analysing the distribution of the OOIS subject areas, it can be found that the areas of increasing interest in OOIS include OO methodologies, OO reusability, application of OO approaches, OO software engineering and OO Web and hypermedia. The areas of declining interest include OO modelling, OO environment/tools and OO knowledge bases. But the decline of research in certain areas by no means shows that those areas were no longer important in OOISs.

With the fundamental studies on OOISs and the analysis of their domain coverage, a generic structure of the OOIS knowledge hierarchy can be derived in Figure 1.
Progress and trends in OOIS technologies. Reviewing the work on OOISs with regard to the generic structure of OOISs described in Figure 11.1, it has been found that research interests in OOIS have mainly focused on how to develop new systems. Increasingly important aspects of OO reengineering of legacy information systems have been left relatively uncovered. Thus, research on methodologies, processes and case studies of OO reengineering of a large number of legacy systems would be a worthy area to explore. Some other trends identified are for example, development of formal OO methodologies, temporal OOIS technologies and development of integrated OOIS tools.

Conclusion

This paper has reported on basic research in seeking the foundations of OOIS. Fundamental concepts of object, information, information system, object-orientation, OOIS and their relationship have been formally described. A generic structure of OOIS has been derived. Based on a review of the past OOIS proceedings, trends in OOIS research and development have been analysed.

Trends of OOIS technologies in reengineering, development of formal OO methodologies, temporal OOIS technologies and development of integrated OOIS tools have been identified for future research.
References


