I

Information Systems and Systems Theory

Ovsei Gelman
National Autonomous University of Mexico (UNAM), Mexico

Manuel Mora
Autonomous University of Aguascalientes (UAA), Mexico

Guisseppi Forgionne
University of Maryland Baltimore County, USA

Francisco Cervantes
National Autonomous University of Mexico (UNAM), Mexico

INTRODUCTION

The information systems (IS) field has been recognized as a scientific discipline since the 80's, as indicated by: (i) the existence of an intellectual community related with doctoral programs and research centers around the world that generates scientific knowledge and solves practical problems using standard scientific procedures accepted and regulated by this community, and (ii) the diffusion of scientific knowledge related with IS through research outlets and research conferences under a rigorous peer-based review process.

Nonetheless, the discipline of information systems has been critiqued by: (i) the lack of formal theories (Farhoomand, 1987, p.55); (ii) the scarce utilization of deductive and formal (e.g., logical-mathematical) research models and methods (idem, p.55); and (iii) the lack of a formal and standard set of fundamental core well-defined concepts associated with the central object of study in this discipline (Alter, 2001, p.3; Banville & Landry, 1989, p.56; Wand & Weber; 1990, p.1282). Consequently, a common-sense language based on informal, conflicting and ambiguous concepts is used as the communicational system in this discipline (Banville & Landry, 1989), and this approach hinders the development of a cumulative research tradition and delays the maturation of the field (Farhoomand, 1987; Wand & Weber, 1990). Furthermore, a deep examination (Mora, Gelman, Cervantes, Mejia, & Weitzenfeld, 2002) of definitions of the term information system, reveals that fundamental concepts are based on few and misused core concepts from the theory of systems (Ackoff, 1960, 1971) and the few formalization proposals (Alter, 2001; Mentzas, 1994; Wand & Weber, 1990) are incomplete.Therefore, the reduction of the lack of formalization of the core concepts used in the IS discipline becomes a relevant and mandatory research purpose. This article contributes to the IS literature with the adaptation and extension of previous formal definitions reported of the terms *system* (Ackoff, 1971; Gelman & Garcia, 1989) and *organization* (Mora, Gelman, Cervantes, Mejia, & Weitzenfeld, 2002) based on the core principles from the Theory of Systems and with the proposal of a formal definition of the term *information systems.* The article also examines the implications for IS research and practice.

BACKGROUND

The term *information system (IS)* has been widely defined in textbooks. Table 1 shows a sample of the main definitions posed in the literature. An examination of these definitions suggests that the IS notion: (i) lacks fundamental standardized and formal concepts (Alter, 2001); (ii) lacks competitive formal macro-structures to cumulate

Table 1. A sample of informal definitions of "what is an information system"

Definition	Reference
"An IS is a system composed of subsystems of hardware, programs, files and procedures to get a shared goal."	(Senn, 1989, p.23)
"An IS is a system composed of application software, support software, hardware, documents and training materials, controls, job roles and people that uses the software application".	(Hoffer, George & Valacich, 1996, p.8)
"An IS is a system composed of inputs, models, outputs, technology, data bases and controls."	(Burch & Grudnitski, 1989, p.58)

theories (Farhoomand & Drury, 2001, p. 14); and (iii) has an excessive variety of micro-theories (Barkhi & Sheetz, 2001).

There have been few, if any, efforts to formalize the discipline. Despite attempts to reduce ambiguity, the proposals (Alter, 2001; Wand & Weber, 1990) have been underpinned on partial views – e.g., syntactical and structural perspectives that hide core semantic information – of what is a *system* (Mora, Gelman, Cervantes, Mejia, & Weitzenfeld, 2002; Sachs, 1976). Others (Mentzas, 1994) offer a more articulated definition than exhibited on Table 1 – by the identification of five subsystems and their functional properties – still lack formalization due to they were developed using a common-sense language critiqued in the IS literature (Banville & Landry, 1989). Therefore, the concept *information system* has still multiple meanings. A systems-based research stream (Alter, 2001; Mora, Gelman, Cervantes, Mejia, & Weitzenfeld, 2002; Paton, 1997) combined with an ontological perspective (Wand & Weber, 1990) suggest that formal foundations from the Theory of Systems (Xu, 2000, pp.113) can reduce this ambiguity and strengthen the rigor that a scientific discipline requires to mature and simultaneously to be relevant and useful for practitioners.

MAIN THRUST OF THE ARTICLE

Formalization reported in this article is adapted and extended from previous work by the authors on the formal concepts of *system* (Gelman & Garcia, 1989) and *organization* and *business process* (Mora, Gelman, Cervantes, Mejia, & Weitzenfeld, 2002). This conceptual development follows a ontological path to define primitive concepts and postulates to derive updated definitions of the constructs *system-I, system-II, general-system, organization, business process* and finally *information system*. A similar approach was used by Wand and Weber (1990) and Wand and Woo (1991) to define what is an *information system* and what is an *organization*.

Formal Definition of System-I. An object of study **X,** formalized as ***system-I*** and denoted as $\mathbf{S_I(X)=<B(X),RB(X),E(X)>}$**,** is a whole **X** that fulfills the following conditions: (I.1) it has a *conceptual structure* **§(X)** that defines its set of *attributes* **B(X)**, its set of *events* **E(X)** and its set of *range of attributes* **RB(X)**; (I.2) for any subset **B'(X)** of *attributes* of **B(X)**, the set of *events* **E(X)** associated with **B(X)** differs in at least one element from the set of *events* **E'(X)** associated with **B'(X).**

Therefore, to define a situation of study as a *system-I* implies to specify $\mathbf{S_I(X) = <§(X)> =<B(X), E(X), RB(X)>}$ and to fulfill the condition (I.2).

Formal Definition of System-II. An object of study **X,** formalized as ***system-II*** and denoted as $\mathbf{S_{II}(X)=<C_X, \Re_S(C_X')>}$ is a whole **X** that fulfills the following conditions: (II.1) the whole **X** is a set $\mathbf{C_X}$ of elements $\mathbf{X_1, X_2, ..., X_k}$, called *subsystems*, where each $\mathbf{X_i}$ for i=1,2,..., k can be formalized as $\mathbf{S_I(X_i)}$ or $\mathbf{S_{II}(X_i)}$; (II.2) there is a collection finite $\mathbf{\Re_S(C_X')}$ of *set-relations* where $\mathbf{\Re_S(C_X')=\{ \Re_1(C_X'), \Re_2(C_X'),\ldots\}}$ on the set $\mathbf{C_X'=\{C, S_I(X)\}}$ and where each *set-relation* $\mathbf{\Re_P(C_X')=\{ {}_p\Re_1, {}_p\Re_2, \ldots \mid {}_p\Re_n = < X_i, {}_ia_j, X_j > \text{ or } {}_p\Re_n = < X_i, {}_ia_X, S_I(X)> \text{ or } {}_p\Re_n = < S_I(X), {}_Xa_j, S_j>}$ and $\mathbf{{}_ia_j}$ stands by the output-input parameters or acts between the two elements}; and (II.3) exists at least a *non-directed-path* among two any items X_i and X_j in the *set-relation* $\mathbf{\Re_S(C_X')}$.

It must be noted that: (i) condition II.3 assures that for any two elements X_i and X_j in the multi-digraph **X**, X_i is reachable from X_j and vice versa; (ii) it is a recursive definition to let a *subsystem* has *subsystems;* and (iii) this definition updates previously reported by authors to consider the output/input relationships between any *subsystem* and the whole *system*. Therefore, to define a situation of study as a *system-II* implies to specify: $\mathbf{S_{II}(X)=<C_X, \Re_S(C_X')>}$ where $\mathbf{C_X=\{ S_I(X_i) \text{ or } S_{II}(X_i) \}}$ for i = 1,2, .., k; $\mathbf{\Re_S(C_X')=\{\Re_1(C_X'), \Re_2(C_X'), \ldots\}}$ and the fulfillment of the condition II.3.

Formal Definition of System as General-System. An object of study **X,** formalized as ***general-system*** and denoted as $\mathbf{S_G(X)}$, is a whole **X** that can be defined simultaneously as a *system-I* $\mathbf{S_I(X)}$ and as a *system-II* $\mathbf{S_{II}(X)}$.

Postulate 1. Any *general-system* $\mathbf{S_G(X)}$ defined as *system-I* $\mathbf{S_I(X)}$ can be mapped to a *system-II* $\mathbf{S_{II}(X)}$ and vice versa.

Auxiliary Definition 1. Suprasystem. A whole **SX** is called the ***suprasystem of a system X*** and it is denoted as **SS(X)** if (IV.1) the whole **X** is a *subsystem* of **SX**; and (IV.2) **SX** can be formalized as $\mathbf{S_I(SX)}$ or $\mathbf{S_{II}(SX)}$.

Auxiliary Definition 2. Envelope. A whole **EX** is called the ***envelope of a system X*** and it is denoted as **EE(X)**, if (V.1) the whole **EX** is the *suprasystem* of the *suprasystem* of **X**; and (V.2) **EX** can be formalized as $\mathbf{S_I(SX)}$ or $\mathbf{S_{II}(SX)}$**.**

Auxiliary Definition 3. Environment. A whole **WX** is called the ***environment of a system X*** and it is denoted as **W(X)**, if (VI.1) **WX** can be formalized as $\mathbf{S_I(WX)}$ or $\mathbf{S_{II}(WX)}$ and (VI.2) **W(X)={SS(X), EE(X)}.**

Postulate 2. Any *general-system* $\mathbf{S_G(X)}$ has a *suprasystem* **SS(X)** and an *envelope* **EE(X)**.

The first formal definition of the concept *system* – for example, *system-I* – accounts for the conception of an external view that sees the *system* as a single-unit with special characteristics – called, *attributes* – and potential acts to execute – called, *events*. In turn, the second formal definition – for example, *system-II* – represents the more usual view – for example, the internal view – that sees the system as a digraph. Furthermore, the definitions of the *set-relations* $\mathbf{\Re_1(C_X'), \Re_2(C_X'), ..., \Re_m(C_X')}$ consider the *system* as a multi-digraph instead of digraph and therefore