Computer Science and Information Systems

Rekenaarwetenskap en Inligtingstelsels
Information Systems Research: A Teleological Approach?

The request to write this editorial came at a very opportune time, coinciding as it did with an intense examination of the development of the field of information systems and an analysis of the progress of IS research. I have therefore used this opportunity to focus my thoughts and outline some of my conclusions. By doing so I don’t pretend to answer any questions, merely perhaps to stimulate thought amongst those SACJ readers involved in IS research.

The last fifteen years has seen a tremendous growth in the study of information systems. During this period a number of journals devoted to IS research appeared such as MIS Quarterly, The Journal of MIS, Information and Management and Data Base. There are now many research-based activities: the International Conference on Information Systems; the annual IS doctoral dissertation colloquium; and various awards for IS research contributions. Hundreds of universities worldwide have formed information systems departments with (reasonably) standard curricula.

Yet with all this, what has really been achieved from a research viewpoint? Are we any closer to understanding the true nature of information systems? Is there a general unified theory of information systems? Is there even an accepted, unique body of IS knowledge? The answer to all of these must surely be no.

We have, I believe, achieved precious little. Yes, we do understand something of IS development approaches. We understand a little more now than we used to about how users interact with systems. But to get back to the first question, do we really understand what information systems are and how they work? No. Which begs the question: Why not?

There are, again I believe, a number of reasons, but the foremost must be that the majority of people in the IS research community either reside in the business schools of the USA or are drawn from other disciplines. These people, it would appear, are researching for research’s sake; to publish in order to secure tenure or develop a research track record, not to further the body of knowledge of the subject. There seems an almost frantic zeal to generate and test hypotheses, trying to adopt and pursue what is seen to be a “scientific approach”. But there is very little focus - there can’t be, or the answers to my questions earlier would be yes rather than no!

Let me hasten to add that there is nothing unique about these IS researchers. "Publish or perish" is still very much alive and well! But also they are really not all that different from other social scientists. As Nagel [3] observed:

"... in no area of social enquiry has a body of general laws been established, comparable with outstanding theories in the natural sciences in scope of explanatory power or in capacity to yield precise and reliable predictions ..."

Why should this be the case? Is it because the great intellects gravitate to the natural sciences and the social sciences pick up the second best who are incapable of generating these general laws? I hope not! The answer may well be that we have become locked into a particular research approach which is inappropriate to developing a body of social science, and more particularly, IS knowledge. Maybe we should be learning from our own source discipline (systems theory) and be developing a real research approach which complements our field of study.

To explore this further let me go back to the roots of information systems. What is an information system? Do we really have an accepted definition? Probably the most widely referenced is that provided by Davis and Olson [2]:

"an integrated, user-machine system for providing information to support operations, management and decision-making functions in an organization. The system utilizes computer hardware and software; manual procedures; models for analysis, planning, control and decision making; and a database".

Note how this emphasizes the man-machine interrelationship and underscores computers as a core component when they are not even necessarily a part of the information system. The worst aspect is that it does little to describe what a system is, and this may well be one of the causes of our research dilemma. Again, if we draw on systems theory then a more appropriate definition might well be: "a hierarchical set of procedures utilizing information to monitor and control organizational performance". Note that this definition fits with general systems theory that all systems have four basic foundations: cybernetics, hierarchy, control and information [1].
An additional aspect not apparently recognised by IS researchers is that the information system, just like any other system, biological or otherwise, suffers from the problem first identified by our own Jan Christiaan Smuts [4]: that of holism. Simply put, this says that the whole is greater than the sum of the parts. This means that information systems, unlike science, cannot be reduced to simple isolated fields of enquiry and then analyzed or tested using hypotheses and laboratory experiments from which elaborate generalizations may be inferred. They have levels of complexity with new factors emerging at each level. The problem with most of the current research is that it starts out with a reductionist approach and then focuses on the highest (or lowest) level. Thus the majority of the topics have as their target the interaction between user and computer or the management or application of technology. There is very little research that is taking place at fundamental level, that of developing a general theory of information systems. This is the teleological approach, searching for the natural laws and developing the theory based on deduction and logical development. Until we can advance that area of knowledge and, from a basis of these fundamental laws, develop a hierarchy of hypotheses that can then be tested, we will have little focus to our IS research. It will remain a fragmented, uncohesive smattering of the work of individuals who are merely grasping at tenure. There are few people who would today argue against the inclusion of information systems as a field of study at a university or as a fruitful research area. But until such time as we focus on the foundation theory, it will remain unstructured and immature.

References


Prof Peter Lay  
Assistant Editor: Information Systems

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Department of Computer Science  
University of Cape Town
Homological Transfer: an Information Systems Research Method

J Mende

Department of Accounting, University of the Witwatersrand, WITS, 2050

Abstract

Information systems are members of a large class of similar systems called "productive processes". The existence of similarities between manufacturing, financial, educational, informational and other productive processes implies that the corresponding subjects Economics, Finance, Education, Information Systems, and so on should contain similar laws and techniques. Therefore many a law or technique $M_x$ that has been discovered in one productive subject $S_x$ can potentially be transferred to another productive subject $S_y$ as a homologous law or technique $M_y$. These transfers can be accomplished by a five-step procedure:

1. Recognise the similarity between $S_x$ and $S_y$ processes.
2. Replace $M_x$ concepts by concepts of $S_y$.
3. Verify $M_x$ relationships for the $S_y$ process.
4. Re-use known $M_x$ reasoning for the $S_y$ process.
5. Extend the reasoning to include unique concepts and relationships of $S_y$.

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1. Introduction

An earlier paper in this journal [34] suggested inter alia that homologous laws and techniques should be capable of being transferred between the subject Information Systems and parallel subjects which study systems of similar structure and function. The present paper pursues that suggestion in detail. First it provides underlying reasons why homologies exist and why homologous transfers should be possible. Then it identifies five steps that are necessary in order to effect those transfers. Finally it outlines two actual research projects in which the five-step procedure was used to transfer laws and techniques from Economics to Information Systems and from Information Systems to Education.

2. Why homological transfers?

In order to satisfy his creature needs with minimum effort, Man has established a network of productive processes. These include:

- farming, fishing forestry and mining processes which produce materials
- petroleum and electricity processes which produce energy
- manufacturing and construction processes which produce artifacts
- transport, logistical and marketing processes which produce movement
- financial, legal and medical processes which produce services
- education and training processes which produce human capabilities
- clerical, computer and publication processes which produce information
- research, innovation and managerial processes which produce designs and other productive processes.

The various process types differ in many of their detailed features. However they are similar in their more abstract features. For instance each process type:

- receives inputs from external sources (the sources may be Nature, human workers or other productive processes)
- provides outputs to external users (the users may be human consumers or other productive processes)
- carries out transformation operations on the inputs to produce the outputs.

So all productive processes are similar in overall structure (figure 1).

Every productive process also:

- receives inputs that are costly to their sources
- provides outputs that are valuable to their users.

A process would neither be established nor continue to exist unless the value of its outputs exceeds the cost of its inputs. Therefore all productive processes perform a similar function, namely to add value to their inputs.

The existence of structural and functional similarities between different productive processes implies that similarities should also exist between models of those processes. A model may be:

- a set of laws which describe interactions among the components of a productive process and its environment [24 & 38]
- a technique which prescribes the steps people should take in manipulating productive components and interactions [9].

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Naturally the existence of differences between the various process types implies that differences should also exist between the corresponding productive models.

Over the ages, researchers have discovered many productive models. In order to cope with the differences between the various process types, educationalists have partitioned the set of productive models into "subjects". Thus some educationalists specialise in the subject Microeconomics which contains models of manufacturing processes. Some specialise in the subject Finance which contains models of financial processes. Others specialise in the subject Information Systems which contains models of informational processes, and so on.

However this compartmentalisation obscures the similarities between the various productive process types. An educationalist in subject S₀ is unlikely to know that a similar model exists in subject S₁. When a researcher in subject S₀ discovers a new model, he is unlikely to know that the subject S₁ already contains a similar model.

Both educationalists and researchers in productive subjects could benefit by an awareness of such similarities [5, 20, 23, 25, 26, 43]. General System theorists have attached the name "homology" [46] or "isomorphy" [43] to those similarities, and have explicitly identified several homologies between existing productive models [2, 7, 10, 11, 12, 17, 19, 29, 39, 45, 47, 48]. Economists, Operations Researchers and Information Systems academics have also contributed to our awareness of process similarities. They have implicitly identified several additional homologies by transferring models from one productive subject to another [4, 8, 15, 18, 37, 44]. However many more homologies probably still remain to be discovered, either by:

- recognising the similarity of two existing models, or by
- transferring an existing model from one subject to another subject in which it has not yet been discovered.

3. Transfer procedure

A researcher can avoid "reinventing the wheel" by transferring a known model of subject S₀ to another subject Sᵢ in which it does not yet exist. The following five steps are necessary in accomplishing such transfers.

1. Recognise Process Similarities

Many models Mᵰ₁, Mᵰ₂, ..., Mᵰᵢ, Mᵰ₂, ..., Mᵰᵢ exist in subjects S₁, S₂, ..., Sᵢ, etc. which study productive processes. Before the researcher can transfer one of these models to a subject S₀ in which it does not yet exist, he first needs to select a particular Mᵢᵣ from the set {Mᵰ₁, Mᵰ₂, ..., Mᵰᵢ, Mᵰ₂, ..., Mᵰᵢ} such that Mᵢᵣ is potentially transferable to S₀ as a homologous model Mᵢᵣ.

A homology reflects a similarity between two productive processes. Therefore if a model Mᵢᵣ is homologically transferable, then the process studied by its subject Sᵢ must be similar to the process studied by Sᵢ. Thus process similarity serves as a selection criterion. Consequently a homological research project should start with the identification of two similar processes.

2. Replace concepts

Homologous models are "formally identical but pertain to different phenomena" [46]. Each model expresses one or more relationships between a set of concepts [3]. Therefore homologous models Mᵢᵣ and Mᵢᵣ express similar relationships between different concepts in Sᵢ on the one hand and Sᵢ on the other. Consequently in order to transform Mᵢᵣ into Mᵢᵣ the Sᵢ concepts must be replaced by Sᵢ concepts.

3. Validate Relationships

Concept replacement transforms Mᵢᵣ from a valid model
of $S_x$ into a potential model $M_0y$ of $S_0$. However $M_0y$ is not necessarily a valid model of $S_0$ because its relationships have only been proved valid for the process type studied by $S_x$. Therefore in order to complete the transfer, the $M_0y$ relationships must be proved valid for the $S_0$ process type too.

$M_0y$ can be validated empirically, by checking many $S_0$ processes to see whether its relationships represent them accurately. For example, Ohm used the empirical method to validate the relationship $V = IR$, his electrical homology of Fourier's heat-flow model [42].

4. Re-use the Reasoning
Alternatively $M_0y$ may be validated by theorem proving [22]. This method is feasible if $M_0y$ is a conclusion derived from the $S_0$ relationships $r_{x1}$ $r_{x2}$ ... by a train of logical reasoning: $M_0y < = = r_{x1}$ $r_{x2}$ ....
In this case homologous premises $r_{01}$ $r_{02}$ etc. may already have been proved in $S_0$; otherwise they can be validated empirically in step 3.

Then the homologous conclusion $M_0y$ can be derived from $r_{01}$ $r_{02}$ etc by re-using the same train of reasoning with different premises: $M_0y < = = r_{01}$ $r_{02}$ ....

5. Extend the Reasoning
Productive processes have some similar features - reflected by similar relationships such as $r_{01}$ and $r_{x1}$, $r_{02}$ and $r_{x2}$. However other features are different, and those differences are reflected by relationships which are unique to each process type. When a unique $S_0$ relationship $r_{0u}$ is added to the premises in the train of reasoning leading to $M_0y$, then a more specific $S_0$ model $M'_{0y}$ emerges from the extended argument

$$M'_{0y} < = = r_{01}$ r_{02}$ ..... $r_{0u}$$.

As the specific model $M'_{0y}$ takes into account more features of the $S_0$ process, it describes the process more accurately and is therefore more useful than the general model $M_0y$. For example, Bohr extended Perrin's planetary homology of the hydrogen atom, incorporating unique angular momentum and energy transition relationships to develop a more accurate model of hydrogen spectra [42].

Figure 2 summarises the procedure in flow chart form. It also indicates the actions to be taken if steps 1, 2 or 3 fail.

To demonstrate that the five-step procedure works, and also to illustrate its applicability, two of the author's previous research projects are outlined in the next two sections.

4. An actual transfer project

The first project transferred a model from the subject Economics to the subject Information Systems. The resulting Information Systems model was published in a previous issue of this journal [36]. The following is a description of the way that transfer was accomplished.

1. Recognise Process Similarities
The subject Economics [31] contains a "production function" model of a firm producing a set of products such as trucks and motor cars from a set of resources such as raw materials, labour and machinery. An information system is similar to a firm. It produces a set of reports from a set of resources which includes data, labour and computing machinery. Therefore the Production Function model was recognised as a candidate for transfer to Information Systems.

2. Replace Concepts
The Economics concepts of resource, discounted cost,
product and discounted value were associated with the corresponding Information Systems concepts of input, cost [27], output and value [1]. In addition, the Economics concept of contribution was imported into Information Systems.

3. Validate Premises
The Production Function model is based on three premises about the typical manufacturing firm. A firm can:
- produce alternative product mixes of different value from alternative resource mixes of different cost;
- use alternative production methods which waste different proportions of the resources; and
- achieve progressively smaller increases in product value by increasing the quantity of any one resource (Law of Diminishing Returns).

These premises were also found to be true of an information system. It can be designed to:
- produce alternative output mixes of different value from alternative input mixes with different costs [28];
- use alternative transformation processes that waste different amounts of inputs, e.g. computer time [35]; and
- yield diminishing returns of additional output value by increasing the quantity of any one input [8].

4. Re-use the Reasoning
From the three premises, Economics proves that:
- some production methods waste resources, and therefore produce fewer products than waste-free methods [13];
- a particular product mix can be produced without waste from several alternative resource mixes, one of which has minimum cost [13]; and
- a particular resource mix can yield several alternative product mixes without waste, one product mix having maximum value [14].

As the subject Information Systems contains homologous premises, the Economics reasoning was re-used to prove similar conclusions for Information Systems:
- some system designs waste inputs;
- many alternative systems can produce the same outputs with different input mixes, one of which has minimum costs; and
- many alternative systems can use the same inputs to produce different output mixes, one of which has maximum value.

These conclusions were confirmed by Kriebel [30] and by Ein-Dor and Jones [18] proceeding from the assumption that Economic Theory applies to all productive processes, including informational processes.

5. Extend the Reasoning
As information is merely one of many resources used by a host organisation, an additional conclusion could be drawn:
- a system which is optimal with respect to waste, input mix and output mix can be expanded to achieve a greater contribution [36].

From the last four conclusions it was shown that an existing system producing value \( v \) with \( c \) can be optimised in four steps:

a. find a waste-free combination of transformation processes giving increased value \( v' \) with decreased cost \( c' \);
b. find the output mix which gives the same value \( v' \) with minimum cost \( c'' \);
c. find the output mix which gives maximum value \( v'' \) with the same cost \( c'' \);
d. find the optimal expansion alternative giving the maximum contribution \( v'' - c'' \).

This led to the definitions of five success criteria:
- overall success \( S = (v - c)/(v'' - c'') \)
- technical efficiency \( T = (v - c)/(v' - c') \)
- economic efficiency \( E = (v' - c)/(v' - c'') \)
- user effectiveness \( N = (v' - c'')/(v'' - c'') \)
- marginal effectiveness \( R = (v'' - c'')/(v'' - c'') \)

Finally the five criteria were shown to be related by the equation: \( S = T \cdot E \cdot N \cdot R \).

5. Another transfer project
The second project transferred a model from the subject Information Systems to the Subject Education. The resulting Education model was published in The Commerce Teacher [32 & 33]. The transfer was accomplished by the following steps:

1. Recognise Process Similarities
The information system development process produces application software from resources such as labour, compilers and hardware. The educational process of developing courses of instruction produces a set of lecture notes and learning aids from resources such as labour, paper, overhead projector transparencies, etc. Therefore the Information Systems model "System Development Life Cycle" was recognised as potentially transferable to Education.

2. Replace Concepts
The Information Systems concepts of information system, system development and program were associated with the Education terms instructional system, instructional design and lesson [21]. The Information System concepts environment, user, supplier, input and output were imported into Education as generalisations of child/student, library/audiovisual-supplier, lesson/lectures and attitudes/skills.

3. Validate Premises
The Information Systems Development Life Cycle is based on three premises:
• an information system interacts with a dynamic environment which can supply alternative inputs and use alternative outputs;
• an information system includes a complex set of interdependent programs developed by the host organisation; and
• system success increases asymptotically with development effort.
Replacing Information Systems concepts with the corresponding Education concepts, similar premises were also found to be true of an instructional system [6, 16, 21, 32, 41].

4. Re-use of Reasoning
Unpublished Information Systems lectures by the author derived three information system development steps from the premises:
• program interdependence necessitates a design phase prior to programming;
• the existence of alternative inputs and outputs requires a specification phase prior to design; and
• environmental changeability calls for analysis prior to specification.
Since homologous premises hold in Education, this reasoning was re-used to prove that instructional system development should involve the four steps: analysis, specification, design and lesson compilation. These conclusions were subsequently confirmed by Romiszowski [40].

5. Extend the Reasoning
From the Education premises two additional development steps were shown to be necessary:
• asymptotic improvement calls for frequent system evaluation; and
• environmental changeability calls for infrequent environmental monitoring.
Figure 3 illustrates the resulting development cycle.

6. Conclusion
When an existing model in one subject is homologically transferred to a second subject, the new model constitutes a discovery in the second subject. For instance, the success criteria T, E, N and R are discoveries in the subject Information Systems. Similarly the development cycle (analysis - specification - design - compilation - evaluation - monitoring) is a discovery in the subject Education. Therefore the five-step homological transfer procedure can be regarded as a research method.

This method is very efficient, enabling a researcher in one subject to avoid re-invention by utilising previous discoveries in other subjects. It is also likely to be widely applicable, because Man employs very many productive processes and all these are inherently similar in function and in structure. So Information Systems researchers can use this method to generate many rapid advances both in their own subject and also in parallel subjects that study similar productive processes.

References


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