A Theoretical Base for High-level Simulation of Organisational Information Systems

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ABSTRACT: The design of organisational information systems is a study of the complex. An organisational information system in the Human Activity System sense, is the sum total of all that contributes to distributing information within an organisation. This includes the human actors participating in the system. Managing information about such a system is a difficult task. Technical support for measuring organisational information systems and comparing different ideas about organisational information systems would thus be useful. A high-level simulation of information systems could be such a technical support. There are a number of issues making such a simulation infeasible today. These mainly arise from the complexity of the simulation model, and in consequence of the data input problem. However, by introducing isomorphism and object templates, it is possible to solve some of these problems. In order to utilise these approaches, a framework for isomorphic simulations need to be developed.

KEYWORDS: Information system, social system, social simulation, systems design, ImAOS

Introduction

In the words of this article, an information system is all that within an organisation contributing to the distribution of information. The information system consists of nodes capable of holding information, channels able to distribute information and actors acting and re-acting upon the information. Thus the actors - the humans within the organisation - are *parts of* the information system rather than *users of* the information system. With this definition, there is no such thing as an information system without people.

Since the actors are parts of the system, and since "the system" is our arbitrary grouping of the activities and components we study, the information system can be characterised as a human activity system in the sense of Checkland and Scholes (1997). The system is an aggregate function of the organisation, its people and its technological artefacts. The higher-order object, the human activity system, the "information system" does not exist as a separate tangible object. It is rather an abstraction, a holon, to which it is convenient to attach properties and behaviours. When further mentioned, the term "information system" shall denote this abstraction as described above.

To clearly make the distinction between the information system in the mentioned sense, and things like software systems or simple computer systems, the term used in the following will be "organisational information system" (OIS). Further, the purpose of the OIS is to keep all parts of the organisation supplied with the information needed to keep the organisation running, and thus not only to supply decision-maker with bases for decisions. Please note that the term OIS has been used in other contexts, but that no reference is made to those contexts here: The meaning of OIS is the one stated here.

With the above definition of OIS, information systems design (ISD) is a study of the complex. By following a set of recommendations and rules, the designer is supposed to collect information about an intended system, construct a feasible compromise between users and management, and produce a technically coherent setup corresponding to all that was wished and wanted. In the best of cases, the setup can be incrementally tested through prototyping, but in the case of larger information systems on the organisational level, this is often too expensive.

To design organisational information systems this way is the commonly accepted approach today, since there simply is no better way to do it. The alternative is *ad hoc* development which, while not uncommon, often results in badly organised and poorly documented organisational information systems which do not support the organisation in an efficient manner.

The current situation, with complex realities and systems development methods of varying applicability, is usually not questioned unless it leads to an economic disaster in the case of a malformed organisational information system. It is not questioned why we only have *normative* and *prescriptive* methods, while there is a distinct lack of ways to do pre-fact *evaluation*, *comparison* and *prediction* of IS concept sketches.

There may of course be reason to question whether the problem with inefficient organisational information systems arise from deficiencies in the development methods, in lack of resources or perhaps even in the inexpert application of the said methods. I do not address these questions. My aim with this article is to demonstrate that there is, at least in theory, another solution available. Namely, that current-day OIS development methods be *complemented* with another layer, namely that of isomorphic social simulation on an organisational level (isomorphism will be discussed in more detail below).

Until the last few years, the simulation technologies available for use have been too limited to be even considered for massively complex simulations such as an isomorphic simulation of a complete organisational information system including both the human actors and the technological used by these actors. However, simulations of a less complex kind have been widely accepted within a number of social sciences fields, such as economics, for many years (Hanneman & Patrick, 1997) .

Goldspink (2002) reviews existing theory concerning tentative purposes of simulations and points out keywords like "prediction", "performance", "proof", "discovery", "assess stability" and "construct working systems". Intuitively this has a correspondence with ISD.

Traditionally, the social simulations field has been focused on "neat" equilibrium models formulated as equations. These have been targeted more at capturing a whole within the frame of one formula rather than trying to model empirically observed phenomena. However, during the 90's a shift in aim has occurred, and simulationists have become more interested in being empirically close to real-world phenomena. (Pyka, 2001). Further, agent-based approaches have recently gained momentum, and show a promising future (Sen, 1997).

In the game industry, life-like simulations have been available for some time. The inspiration for the kind of simulation presented below did initially come from "The Sims" (Electronic Arts, 2004), a game which simulates social relations with an overtly isomorphic focus. The inspiration was that something similar should be possible to do for organisational information systems.

It should be noted that the discussion is mainly based on literature, but also partly on experiences from previous work in close relation to a case scenario at the Swedish National Defense College (Egonsdotter & Palmius, 2002) (Palmius et al, 2003). Because of this, some interpretations may be skewed towards military practices.

In the following, I will first specify how a simulation could be used and why. Then I will point out some problems that make simulations infeasible today. Finally I will suggest how these problems could be addressed.

The purpose and use of a simulation

The application of simulations in the context of this article is to *support* organisational information systems development through adding additional points of evaluation and elaboration during the development project.

Organisational information system sketches and models can be *evaluated* through the use of the simulation approach. The evaluation produces measurements relevant for comparing different options. It can also detect congestions and underfeeds. The evaluation is quantitative. Examples of outputs from the evaluation is "information takes in average five hours in propagating from point A to point B", "person C has a projected overload of 125% information messages and can therefore be counted as a point of congestion" and "information directed to person D underfeeds with a projected propagation factor of 43%".

The development can also be *elaborated* through the use of a simulation approach. This is not an exact output, rather a qualitative study of effects. Information transmissions and actor behaviour can be studied real-time. Examples of output from this can be "look, person A and person B never meets in person despite working close organisationally speaking. Perhaps they should have offices next-door?" and "What happens if we move the main bulletin board from this corridor to the coffee room?". The elaboration takes place in the manner that pieces of a system sketch can be moved around to gain an understanding in options and effects.

Before starting to apply the simulation approach, it is assumed that the user (the systems developer) has an organisational information system he is interested in studying. This organisational information system may be an existing or a planned system, but there must be at least an idea about an organisational information system.

It is further assumed that the developer has a goal associated with working with the organisational information system. This goal might be "to improve efficiency in information propagation" or "to support organisation viability through providing accessible information".

The simulation approach is not necessarily dependent on any specific systems development model and/or method. In this article, it is assumed that the developer approaches the development with a soft (SSM) view, and that there are distinct moments in time when an intervention into the development is feasible.

It is assumed, but not necessary, that the developer retains a Soft Systems Methodology (SSM) perspective (Checkland & Scholes, 1997) designing and developing systems. The language in this article builds on a SSM worldview. For example, "the system" is an abstraction, not a physical object. Another example is that the purpose of design is to produce "culturally feasible" and "systemically desirable" systems.

The simulation approach presupposes reasonably large organisations contained within one geographically delimited area, such as a building. There is no upward limit in size, as long as the geographically delimited criterion is met. However, small organisational information systems (say, an organisation with less than 20 employees) will be pointless to simulate. The simulation approach depends on overall human behaviour models and in small samples, the individual-dependent variables will have too much impact for the simulation to perform. Further, in a small-scale IS, the complexity level will approach being low enough to overview, and thus a good developer will perform better intuitively than the simulation can ever hope to contribute.

What makes simulations infeasible today?

There are several issues which make the use of simulations as a support for ISD infeasible today. A short summary of these issues are:

Complexity

The greatest problem with simulating all kinds of social systems is that of complexity. The social system is inherently complex, since the actors (humans) display a very wide variety of behaviour and seldom follow an easily reproducible pattern. The problem boils down to a fundamental conflict: Do we reduce the system in focus to the extent that it is possible to overview, even though this causes the simulation to no longer bear even the closest resemblance to the system in focus? Or do we accept the richness of the social system and try to implement this in the simulation, even though this causes "bloat" in the software and we no longer have detailed understanding of the higher-order systemic level construed of the relation between all the processes and events?

The second problem is in part caused by the first. If we try to describe a very complex reality, we have a huge task to address in data input. For example, if we are to simulate organisations with several actors, each of which have their own agenda, designated role, geographical turf, informal relations and pre-knowledge, then we would of course need to design how the simulation should represent all this. Depending on the chosen balance between complexity and reduction, we would need to enter the detailed information for each new organisation to simulate. This would be a very time-consuming task, even disregarding the fact that we would have to gain the knowledge about the studied phenomenon first (possibly by observing the organisation and actors we wish to simulate).

As a consequence of the data input problem, the cost becomes an unreasonable factor. The cost of performing the observation needed for the data input and for entering the data itself would be many times greater than the perceived gain in having performed the intended simulation.

Measurements, ontology and epistemology

No matter which balance between complexity and reduction being chosen, a reduction must be done. All models are reductions of reality. The problem is how the reduction should be made, not if it should be done. However, when reducing reality, care must be taken that important entities are treated fairly. The reducer need to know both which entities to represent, and how to name these. We can perceive two abstract realities: The object system and the simulation system. They are abstract even if they exist, because realities are *our definitions of those realities*. Those definitions consist of a view of what exists (the ontology) and how we describe that (the epistemology). While such definitions exist both for the perceived reality and the simulation reality, they do currently not easily map onto each other: there is a gap between what we can see and describe in the perceived reality and what we can see and describe in the simulation reality. In order to get good sense and value out of the simulation, the ontologies and epistemologies for both realities need be made explicit and mapable onto each other: The relation between the two realities must be clear.

Partly caused by the uncertainty of the world view, the management of communication channels is a source of error. In an ontology based solely on a formal organisation structure, many of the most important actor-actor links will simply not be visible. On the other hand, in an ontology based solely on ad-hoc communication channels, such as agent meeting agent in a corridor on the way to coffee machine, the formal channels will likely be treated unfairly. A detailed world view description is necessary, and it must contain a viable integration between formal and informal information channels.

As noted by Carley et al (1998), the impact of design perspective in the organisational design versus locally acting agent span, can be quite significant.

As a further consequence of the ontology/ epistemology issue, it is not altogether clear what, more exactly, it is that the simulation is supposed to measure, nor how. Obviously it is "efficiency" somehow, but this term is not yet defined in this context. It would be difficult and likely pointless to conceive a single-value result for the simulation as a whole. For what would an efficiency of "42" tell us?

The organisation around ISD

In the end, the problem which is the most likely to stop simulations for systems design, is the context of systems development projects of today. The project life spans tend to become shorter, and the results they produce become quickly outdated. In this stressful environment, adding another time-consuming phase will simply not be an option. Doing things quickly although not entirely optimal will likely be preferred over doing things more carefully but taking longer time.

Making simulations feasible

The first task here is to assess just how complex the system in focus need be. Fliedner (2001) discusses non-equilibrium systems in hierarchical levels (in a social systems context) and lists a number of population types, their basic tasks and their basic institutions. Paraphrasing him, we could perceive the modeled organization as the sum population. It should be noted that there is a difference between the theoretical sum-total systemic complexity and the actual complexity at one system level. Klir (2001) states that "the first general principle" of a system's complexity is the amount of information required to describe the system. He further states that our ability to understand a system decreases with the number of entities and relations within the system. I shall call this perspective the *theoretical complexity*. This view is of course relevant if the whole system is perceived as one systemic level. However, when taking encapsulation into account and perceiving the system as *several* encapsulated systemic levels, the *practical complexity* of any given systemic level is considerably less overwhelming than the sum theoretical complexity.

When we start to discuss practical complexity rather than theoretical complexity, we can see that one way of handling sum total complexity is through a deep systems hierarchy. This approach is influenced by object orientation and has also been called "embeddedness" (Hanneman & Patrick, 1997). The idea is that complexity can be contained in lower systemic levels, in order to leave the higher systemic levels uncluttered, that each functionality, such as human navigation, can be considered a self-contained sub entity. The higher systemic level (in this case the actor object) does not need to know about the details, as long as there is a well-defined interface for input and output. From the point of view of the actor, the navigation sub system is a black box. Taking the step further, to the simulation systemic level, the actors are considered black boxes.

This approach is already employed within software industry, in component-based development. Once a component functions as to specification, there is no longer any need to consider its internals from the point of view of the top-level software. The component can be "closed" into a black box, and only its interface considered in the development. To use OO terms, this is called complexity containment through encapsulation.

The number of systemic levels are arbitrary: It is a question of practicality. A very complex system will typically have a deeper systems hierarchy, with many layers of black boxes, developed and validated individually. A simple system will be shallow, with as little as two systemic levels.

The idea with all the above is to provide a finished set of black box hierarchies, of archetypical role blocks. The positive outcome of this would be that much of the data input is already done: the things that are archetypically general across many organisations can be inherited rather than re-specified. With a hierarchy of specified objects, much of the data input problem can be solved. While individuals have individual aspects of their behaviour, there is also a great part of the behaviour which is common for the individual's class. Thus, specifying for example the archetype "secretary" provides us with the means of assigning the same basic behaviour to a group of actors, in order to later on either specify the individual variety, or specify that the variety should be emulated through statistical distributions.

Because the greater part of the cost is related to the data input problem, reducing the data input through providing general templates will also drastically reduce the cost.

The measurement problem aspect of the output does not have a clear-cut answer. The system in focus is complex. The goals of the system in focus are complex. The definitions of "good" and "bad" in the system in focus are complex. Thus the measurements need be complex.

Efficiency measurements are of course one necessary point of output, but they depend on what part of the system we are studying. A single efficiency measurement variable for the sum total of the organisational information system is not usable, but a measurement on the level of a few-hop channel might be.

Other viable measurement outputs are overview graphs of how the system functions. One example could be the output of social network graphs as proposed by Klovdahl (1998). Through these it could be possible to get an overview of the aggregate of low-level operations.

The problem with the span between formal and informal channels is in part addressed simply keeping an isomorphic focus in the simulation.

The acting of a designed role is a conjunction of the assigned specific role, and the generic (or at least organisation-wide) human behaviour. All modelled agents move around, speak when meeting each other in lunch rooms or corridors, and have schedules making them available or not available in their rooms.

The idea is that the informal channels arise spontaneously when the assigned roles are acted: If one actor often meets another actor in a corridor, and they exchange information during these chance encounters, then an informal channel has been formed.

It would be counter-intuitive to explicitly model informal channels. However, an organisational design should take the available opportunities for the arisal of informal channels into account. If it is desired that some people speak with each other outside the formal organisation structure, then chances are better that this will happen if they sit close to each other geographically than if they sit in opposite parts of the building.

Introducing isomorphism

One important difference between traditional simulatory technologies such as Cellular Automata (CA) and Game Theory (GT) and the development of the last few years is the emergence of isomorphic approaches. In the isomorphic view, the object of reality should be represented as closely as possible in the simulation, preferably as objects and entities of their own. This has been made possible by multi-level simulation and multi-agent systems. In practice this means that, when simulating a human activity system with technological artefacts, the simulation should contain both a "person" object and, for example, a "computer" object. They should in all likelihood be placed within a spatial model of the building containing the human activity system. The output of the simulation should ideally display something looking like a top-down view of people moving around in the spatial model, doing what humans do, spreading information, going to the coffee machine, talking, working and meeting each other at the lunch table.

In an isomorphic approach, we try to capture reality through the whole process: Input, process and output should have an object-to-object correspondence with the perceived object reality.

It should be noted that the isomorphic view is far from uncontroversial. Traditionalists within the field criticise (and rightly so) the difficulties that arise from a philosophy of science point of view: The variables, both dependent and independent, become so numerous that is practically impossible to do any kind of validation of the simulation model in the traditional sense of the word. The only validity possible here is "face validity": if experts and initiates of the modelled system look at the inputs and outputs, and feel that this gives a believable impression, then some small manner of validation has been reached.

One headache the simulationist using an isomorphic approach soon encounters, is the relation between perceived objects (which are isomorphically modelled) and aggregate or higher-order objects (which are known, but not perceived per se).

In the best of worlds, a simulation would be built only using objects on one systemic level. For example, a simulation of an organisation with an actor perspective would only model actors. The higher-order entities (such as "group", "organisation" and "power structure") would be left to appear spontaneously as a synergetic effect of the interaction between the atomic objects. This would be true isomorphism, as this is how we perceive the system in focus.

However, as all models are reductions, we can not depend on this to necessarily happen. One of the things we in practice are forced to reduce (not exclude, but reduce) in the model is the overwhelming complexity of the relations and interactions between the atomic objects.

In practice, an isomorphic simulation of a complex system will need to implement some aspects of multilevel simulations. If we perceive that "organisation" is an entity, albeit abstract, we will need to model it as an entity with properties and behaviour. The actual implementation is simulation-dependent, but the relation between what we perceive as the atomic objects and the higher-order object needs be made explicit.

As a side note, all isomorphism is a matter of perspective. We *choose* to *perceive* certain entities as atomic. They are not really. They are simply one application of Occam's razor, a selection of which systemic level to put in focus. For example, an actor is made up of sub-systems (cognition, movement, needs...) which in another simulation could be perceived as the atomic objects.

A new framework

One general problem with the word "simulation" is that it is a term used in many fields, and that it there denotes very different things. Simply saying "simulation" is bound to cause confusion. It can mean as different things as studying the result of an equation when changing its base parameters, via deterministic models of electrical circuits when adding or removing components, to massively complex multi-agent and multi-level studies of social contexts.

One way of getting around this is by defining "simulation" in the context of an article, and then blame the reader if he did not read or understand that definition. Another way is to use another, more explicit, term. In the latter option, the problem would of course be to find a term which is not already heavily laden with implications from already existing areas.

I shall in the following use the term ImAOS (Isomorphically Acted Organisation Scenario) for describing the kind of simulation I am after. Having googled for the term, I think the only field it might be already defined in is psychiatry (IMAOS is a class of anti-depressant drugs). I am certain that there will be no confusion between the two fields.

Think of ImAOS as a top-down view (as in geography) of an organisation with actor. When the simulation is started, a view of the building containing the organisation will be displayed. In this, it will be possible to see the actors (humans), computers and other information transmission equipment. The actors walk around as they would do in the real simulation, go to the lunch room and have a cup of coffee, sit at the computer and send a mail, talk in the corridors and attend meetings. While this happens, the person running the simulation can study information channels and actors to see where information piles up, or if there are people who sit idle because they do not get the required information.

As of now ImAOS is mainly a vision of how an isomorphic simulation should look and behave. It is not an existing framework.

Validity and/or credibility

Law and Kelton (2000) points out that the validity of a simulation model is related to what purpose the study has. There is no such thing as a valid model in an absolute sense. Further, they point out that there is a distinct difference between a valid model and a credible model. A credible model is a model that the owner of the project accepts as good. A valid model is a model that is a good approximation of the object reality. These two are not necessarily related.

Byrne (1997) points out that a it is a mistake to treat a simulation as an equivalent to an experiment. The validity in the positivist experiment sense should not be applied to (social) simulations, since the simulation by necessity works through analogues rather than similes.

Let me here state that the primary objective of ImAOS would not be validity in the positivist sense. While being important and something to strive towards, positivist validity is secondary to usefulness, or credibility. A model is good when it is usable for studying a system. The model does not necessarily have to be completely correct in the positivist sense to be usable. Abstractions and metaphors may enhance usefulness while still in the strict sense be deficient to positivist validity.

Also, the completely "correct" model of a social system is a chimera. As noted by Schmidt (2000), human behaviour is not possible to *replicate* in the foreseeable future, and that a good *model* (as opposed to a replica) does not need to conform to reality in all respects.

In some sense the goal and/or format of ImAOS could be classified as "Interpretivism" with a "highly constructivist bent" as described by Halfpenny (1997), although I do not agree with his judgment that this approach is necessarily whimsical.

Conclusions

Trying to build a simulation of a whole organisational information system in order to use it for design and modifications, presents significant difficulties, mainly stemming from the complexity of specifying the simulation model and its contents.

In the above we have seen how the introduction of isomorphism and object templates could solve some of the problems that make simulations of organisational information systems infeasible today. However, this is as of now a theoretical construct, and it needs to be formalised into a coherent framework - ImAOS. It is yet early to predict the full work, but some issues need to be resolved. The theoretical approach need to be made explicit: There should be full and comprehensible ontology and epistemology for ImAOS models in general. The balance between complexity and reduction in the model needs to be made clear.

To make an implementation of ImAOS practically usable, low-level models for agent behaviour, such as communication and navigation, need to be integrated into a comprehensive template structure.

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