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DEVELOPING A METHODOLOGY FOR DESIGNING ROUTINE INFORMATION SYSTEMS BASED ON THE SITUATIONAL THEORY OF ACTION

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Abstract

Information systems are part of purposeful socio-technical systems and consequently theories of action may help in understanding them. Current systems analysis and design methodologies seem to have been influenced only by one particular theory of action, which asserts that action results from deliberation upon an abstract representation of the world. Many disciplines have discussed an alternative 'situational' theory of action. There is no design methodology that fully supports designing systems reflecting the situational theory of action. The aim of this paper is to describe the motivation for, and progress to date of research-in-progress developing a design methodology based on concepts from the situational theory of action. This methodology for designing situational information systems is being iteratively refined using a combination of case studies and action research. This project is significant because many information systems fail in pressured routine environments where we would argue that the situational theory of action provides a better description of purposeful activity.

Key words: Situated action; Routine work systems; Systems development methodologies; Case study research; Action research.

1. INTRODUCTION

In the past 30 years a number of methodologies have been developed to assist information systems (IS) designers to produce and document systems designs. They can be referred to collectively as Information Engineering Methodologies (IEM), with Structured Systems Analysis and Design Methodology (SSADM, the British government standard) being a typical example. These methodologies consist of prescriptive steps to be used in analysis of the task domain, and various design aids used to represent and document the data models upon which databases are created and the processes that occur when transactions are recorded in the system. These methodologies have been widely disseminated through the IS profession by practitioners, consultants and educators. The ability of these information systems to accomplish the goals set by those commissioning them is thus to a large degree determined by the fitness for purpose of these methodologies.

As a means of support for operations, particularly when work is complex, time-constrained but largely routine, systems designed using these methods are often ineffective, inefficient or not accepted by people using them. They work technically, but fail to support routines in the work context. For example, hospital systems often fail to support both the speed with which specialists and surgeons pass through wards visiting patients and the means to collect and communicate information vital for patient care (Hardy and Drury 2001). Data collected is then not reflective of the activities undertaken by the specialists or of the decisions taken. There are consequent failures to manage or measure work practices in the wake of the dirty data created (Lederman 2004). In a manufacturing context Johnston (1995) shows how this mode of system design marginalises the role of the environment (physical and social) of work which is key to understanding the efficiency of routines. An approach different from present systems analysis and design methodologies is needed in order to develop information systems better suited to pressured routine environments.

In previous papers (Johnston and Milton 2001; Johnston and Milton 2002; Lederman, Johnston et al. 2003; Lederman, Milton et al. 2004) we have argued that information systems are purposeful and that methodologies and tools used to build them should be analysed using theories of action, that is theories concerning the nature and design of goal-directed systems. Theories of action have been researched in several disciplines (Brooks 1986; Agre and Chapman 1987; Suchman 1987; Hendriks-Jansen 1996; Johnston and Brennan 1996; Agre and Horswill 1997; Clancey 1997) where two main positions are found which we will call the "deliberative" and the "situational" theories of action. The deliberative theory of action posits that an agent acts in a goal-directed way by building and maintaining an abstract model or representation of the world and applying deductive processes to this representation to determine what to do. Contrastingly in the situational theory, agents respond more or less reactively to situations presented by structured environments without deliberation. The two theories have quite different modes of representation and action selection. We have argued previously that Structured Systems Analysis and Design Methodologies are implicitly informed by the deliberative theory of action, whereas the situational theory provides a better description of the mode of action that takes place in time-constrained, routine work environments.

This paper describes a research project in progress which aims to develop a situational information systems analysis and design methodology explicitly informed by the situational theory of action for application in routine but pressured environments. In this paper we describe and justify the program of research that is in progress, the preliminary results of which will be available early in 2005. The program is important to theory because it uses an approach to design that has not been previously applied to complex socio-technical systems. By undertaking this program, we expect to learn much more about the applicability of the theory of situated action in complex socio-technical cases. We also expect to gain a deeper understanding of concepts such as situation, action, and routine that are central to the theory of situated action. This paper presents the program for realising a methodology for designing situational systems. It is important for information systems practice because a case can be made that it is the implicit commitment to the deliberative approach that underlies ineffectiveness of traditionally designed systems in routine environments and their frequent rejection by users. A methodology for designing systems based on the situated theory of action should make a contribution to remedying this problem. Although open to refining through our research, we view action in routine environments as that where there is no choice for action selection *except* where a routine breaks down.

In this paper we firstly discuss the deliberative theory of action that implicitly informs traditional systems design methodologies. We note that there is another theory of action (the situational theory) that appears to be more useful for explaining routine activity than the deliberative theory. We argue that a design methodology (using the situational theory) is needed because the deliberative theory of action that underpins traditional methodologies is ontologically quite different from the situational theory of action that underpins routine activity. We describe a pilot case study we have undertaken and then give a first cut of design methodology that has come from a study of situational action and partly refined through the pilot study. The research methods for the now in progress two-phase research program for refining the initial design methodology are then described before we conclude. The research program will run for just over three years and we intend conducting up to five iterative case studies followed by a small program of action research.

2. DELIBERATIVE ACTION AND TRADITIONAL SYSTEMS DESIGN

We have argued previously (Johnston and Milton 2001; Johnston and Milton 2002; Lederman, Johnston et al. 2003; Lederman, Milton et al. 2004) that existing information systems implicitly support the deliberative theory of action. According to this theory (Johnston and Brennan 1996), purposeful action proceeds by an agent building an abstract model of the external objective world from sense data and then reasoning about this model to determine actions that will achieve goals. In traditional transaction-based information systems for example, 'transactions' are gathered that represent changes in the world. Data models that correspond to the representation scheme are used to design databases that are updated by the transactions (representing events in the world). In extreme cases, such as Manufacturing Resource Planning, MRPII (Wight 1981), applications programs also deduce goal-attaining actions and human actors are only required to define the goal state, execute the actions in reality by following automatically generated schedules and provide 'sense data' by recording transactions. More typically, applications programs help human actors to make decisions (based on such a world model) by providing information about objects from reality and using data gained through transactions. Decision support systems are good examples of this type of system.

Information engineering methodologies (IEM), share the ontological assumptions of the deliberative theory, namely, that systems should represent the world in which the system acts in terms of external, independent and objective entities, properties and relations (Wand, Monarchi et al. 1995). Given this focus on symbol/object representation, use of these methodologies encourages designs for the socio-technical systems in which information systems form the representational scheme which mimic the deliberative approach to action.

3. SITUATIONAL ACTION AND ROUTINE SYSTEMS DESIGN

Disciplines other than information systems have considered an alternative approach to theorising about purposeful action called the situational theory of action (Brooks 1986; Agre and Chapman 1987; Suchman 1987; Hendriks-Jansen 1996; Johnston and Brennan 1996; Agre and Horswill 1997; Clancey 1997). In robotics specifically, this alternative theory has been motivated by the brittle performance and computation intensity of artefacts based on the deliberative approach. The key to this alternative theory is to provide an agent with largely reactive responses that utilise sense data obtainable directly from the agent's *ground view* of the world, and to introduce the agent's goals and perspective explicitly in the representation schemes implicit in the theory. In the situational theory, agents respond reactively to "situations" without deliberation. Situations are descriptions of the world centred on the agent and only include features of the world that are relevant to the agent's purposes (Agre and Chapman 1987) and related actions. These features consist of the *relations of things to the agent given its goals*. Actions are selected from a repertoire used to respond to situations. This approach to action selection leads to goal attainment only if the agent's environment exhibits structure ("affordances") to obviate the need to plan (Agre and Chapman 1987). An affordance is a structural aspect of the environment which makes it possible for an agent to reach a desired situation (a goal) by merely reacting to its current situation. Analysis and exploitation of environmental structure is an important part of designing situated agents (Agre and Horswill 1992; Hammond, Converse et al. 1995; Horswill 1995; Agre and Horswill 1997). An activity in this theory is a grouping of situations and associated actions that together lead to a reliable reaching of a desirable situation.

We can see the differing role of representation in the situational theory: Situations are agent-centred and intention-laden views of the world for which a symbol/object isomorphism is neither possible nor necessary. The situated agent is not aware of individuated objects in its environment but rather of aspects of situations which betray opportunities for action. To the extent to which these aspects need to be represented in action selection the representations are, according to Agre and Chapman (1987), indexical (agent-centred) and functional (specific to the agents purpose).

The situational theory has a different position on intentionality also. In the deliberative theory goals are desired future states of the world and consequently the apparatus of world modelling is necessary for the agent to act intentionally in the present. In the situational theory, goals are achieved by an orientation of action in the present to likely goal attainment provided by awareness of affordances specific to that goal in the immediate environment. Thus, activities are sets of situational responses that are *about* goals rather than *driven by* goals.

Finally, the ontology that underlies the situational theory differs from that of the deliberative theory. Because the deliberative theory relies on deduction of actions from future objective states of the world it is forced to commit to an ontology of things, properties, relations and world states. The deliberative theory begins with things and properties and derives action as a secondary concept: a particular kind (deliberate) state change. By contrast the situational theory has action, activity (extended episodes of purposeful action) and affordances (possibilities of action provided by structure of environments) as its grounding concepts. Things are apprehended by a situated agent only through their role in affording certain actions, that is, as 'equipment'. This suggests that a system design methodology built upon the situated theory of action should focus on entirely different entities than one built upon the deliberative theory.

Clearly the situational theory of action has much more in common with routine behaviour than the deliberative theory of action. This is because when engaged in routine behaviour one is interested in how an activity is progressing and acting accordingly rather than returning to first-principles and planning. Following a period of gaining experience in recognising situational cues, an agent uses those cues to notice what action is appropriate according to the status of the activity. Consequently, methodologies for designing systems to support routine work would be better built upon the situated theory of action. Our research brings to information systems ideas from diverse disciplines where authors have argued that the "deliberative" theory of action and the "situational" theory of action, are radically different. The situational theory of action has had no significant influence on design of information systems despite there being proof-of-concept through effective and novel systems designs in robotics and artificial intelligence.

4. METHODS FOR CREATING SITUATIONAL SYSTEMS

There are three ways in which a situational system is brought into being. Firstly, a situational system could *evolve* so that agent actions and the effects of actions knit perfectly with environment and situations to make activities reliable. Evolved biological organisms are excellent examples of evolved situational systems (Juarrero 1999) In many cases, such as in social activities, the activity and its environment may have *co-evolved.* Secondly, an agent may *learn* an activity by seeing the effect of actions in specific situations. In this case trial and error is used to find the action rules that best exploit the structures in the environment, but also environments might be chosen because of their particular affordances for action. Thirdly, and this is the approach we propose for information systems, a system can be *designed* so that actions taken in response to situations will have desired effects. Depending on constraints, either or both the action rules and the environment structures will be deliberately designed to ensure the reliability of an activity. It is for this purpose that we propose our methodology, and it is a distinctive feature that “environmental engineering” is part of it. Some level of iteration is also needed. It is on this third basis that we have built an initial cut of the methodology which we detail below.

We have used the situational theory of action, as it is discussed in robotics and other disciplines, to determine the concepts central to an agent-centred situational system design methodology and the steps that are likely. Whereas, the deliberative theory suggests information systems design should emphasise modelling the world using objects, properties, relations and states, and deduction upon these models to determine action (such as decision support and planning), the situational theory should make central the notions of an activity, situations that comprise activities, actions that are largely a reaction to situations and affordances that show the possibility for action, and hence also characterise the situation. The situational theory would emphasise the importance of proper structuring of environments of action, which is largely ignored in the deliberative approach.

Having identified the key concepts important for routine activity we undertook a pilot case study in order to clarify the concepts and to construct a starting design methodology. We expected to learn about the roles of the different concepts and how they are used to construct a design methodology.

5. CASH ENGINEERING: A PILOT CASE STUDY

We applied the methodology to a pilot case study in a compressor manufacturer called Cash Engineering in Richmond, Australia. The methodology was applied to the design of a routine manual air compressor manufacturing system at Cash Engineering. In 2002 and 2003, the managing director of Cash consulted with one of the authors throughout the design of a manufacturing system for a new range of air compressors and the resulting manual control system strongly reflects the principles espoused by the situational theory (Johnston and Milton 2002; Lederman, Johnston et al. 2003; Lederman, Milton et al. 2004).

The re-designed system, known as the Cash Compressor System, is for production control in a small factory of four staff manufacturing about 200 air compressors a year. The system has a white board that represents non-routine aspects of the compressors being made. There are no computers in the factory. What is interesting is how little information is represented on the white board without compromising control or efficiency.

The factory is designed so that the person taking orders on the telephone in the middle of the factory has full view of all available stock on shelves lining the walls. The main components of the system include a white board of open customer orders and the physical parts of the air compressors that, by their construction, implicitly contain information about their own method of manufacture. The information on the whiteboard is job-specific including name of client, and options such as colour, and compressor motor size. The system has been designed deliberately in this way to reduce the need to represent things.

Manufacturing commences when the order is received by phone and a line order is added to the white board. Major parts for making the customer's compressor are checked for availability visually, and if need be, ordered on a one-off basis. Floor stock of other parts is also maintained by reordering based on visual clues. The machine assembler then takes a machine base and begins construction, referring to the white board only for order-specific information that is not part of the standard assembly routine.

What is interesting in the Cash System is what is not represented. There is no detailed information about how to construct the machine: the machine acts as its own "jig" through devices for guiding a tool or part to a specific place. Employees have learned the limited number of techniques used with the "jig". There is no parts-list or inventory of parts: the availability and quantity of parts holdings are clearly seen on the shelfs. The only recorded requirements-related information is in the reference to non-standard choices on the whiteboard.

If this system were to be explained by the deliberative theory of action, representation would include detailed information about each compressor being manufactured. This is not the case at Cash where very minimal information is kept explicitly on the white-board. No rules can be found to enable a worker to take the individual parts and assemble a compressor. Instead we see the next action being afforded to the worker by the structure of part-manufactured machine. Only a limited range of choice is available. When there is a choice, the white-board tells them the option to be selected based on the customer's desires. Similarly, deliberate structuring of the plant environment allows parts to be replenished with little deliberation or planning.

What the Cash system shows is that with careful design of the work environment (including the object of manufacture itself) reliable goal attaining activity can be managed with very parsimonious representational systems of a type rather different to those envisioned by current information systems design theories. Cues for action selection are largely provided by the affordances of the environment and the machine design. The white board represents activities and the choices needed at key situations in the activity. But the representation is more fragmentary and ephemeral than a world model. This is possible because to a great extent "the world (is) its own model" (Brooks 1991) in the Cash system.

The system at Cash Engineering is manual. However, there is no reason why the principles uncovered at Cash Engineering and emerging from the situational theory of action cannot be applied to socio-technical systems involving information and communications technology. It is likely that ubiquitous computing and mobile devices will play a role in structuring an agent's environment and allowing for better communication of situations to and between human actors.

6. AN INITIAL SITUATIONAL DESIGN METHODOLOGY

Reflection on the re-design of the manufacturing system at Cash Engineering which was strongly informed by our understanding analysis of the implication of the situational theory of action for information system design has led us to formulate an initial design of methodology for designing situational systems. The methodology has six steps:

1. **Identify the multiple agents and their specific environments that constitute the total situational system.** Situational systems of any complexity will consist of a multiple of interacting agents (human and technical) each situated in their own unique environment.
2. **Identify the activities needed in the situational systems in pursuit of specific goals.**
3. **Analyse activities of agents into the situations, their aspects, and actions constituting each activity**. Activities can only work if an agent is able to notice when it is in a particular situation and are able to act routinely.

4. **Analyse environmental structures which afford goal attainment for each activity.** Identification of environmental structures is important because they enable an agent to achieve goal using largely reactive situated actions. Thus situated systems design is partly "environmental engineering".
5. **Check analytically whether the environmental structure identified or engineered interacting with the situation-action pairs identified for a particular activity will result in reliable goal achievement.** If not, repeat and refine steps 3. and 4. until activities within suitably structured environments are found which require a minimum number of deliberative choices on the part of the agents.
6. **Identify choices remaining within the situations within activities that are not accommodated by environmental affordances. This will define the function of the informational component of the system which will allow all choices to be resolved by reference to it.** In situated systems the information system component is minimal and remains simply to resolve any non-routine situations.

The final methodology would, once refined, consist of detailed documented guidelines for performing these steps together with appropriate representational analytical tools for many typical working environments. This program of research is focused at taking this starting methodology and finishing with a mature and well supported methodology for designing information systems.

7. A PROGRAM REFINING THE SITUATIONAL SYSTEMS DESIGN METHODOLOGY

We have argued that of the two theories of action, only one is supported by existing systems design methodologies (the deliberative theory). Further, we have argued that routine activity is explained better using the situated theory of action and have used existing literature to describe a first-cut of the design methodology based on the situated theory of action and informed by a pilot case study. We are now refining the design methodology through a two-phase program of research that is currently underway.

Firstly, we are using case studies to adapt the methodology to re-designing but not implementing a range of routine systems. We have chosen sites that cover a diverse range of routine systems in a range of operational environments. This will ensure the methodology is adaptable and help to define any limits to its applicability. The re-designed systems are not implemented as part of the method. Instead, the case studies are used to fully explore the methodology and to build up know-how about its application in practical circumstances.

Secondly, following the case study phase we will apply and modify the fully operationalised methodology using at least one action research cycle in a different organisational setting. In each action research cycle we intend implementing a routine system and actively reflecting upon the design methodology and its application. We cover the two parts of the program in the following sub-sections.

7.1 Case Studies

The method for this part of the program consists of successively refining and more deeply understanding the situated systems design methodology by re-designing existing systems (without implementing the new system). In this, a researcher is completing successive participatory case studies of a range of routine systems in organizations by applying the methodology to re-design the chosen system.

In each case study the researcher is learning an existing routine system in order to fully understand the goals for the system. Following this familiarisation period the researcher uses the situational design methodology to re-design the system. Embedding a researcher in a system where they participate in the old system before redesigning it is appropriate because it is only by being situated as an actor in the system that the researcher can appreciate what is needed for an actor in the situated version of the system. The case study is completed by an ontological analysis and independent inspection of the design documents together with a comparison with the original system to confirm that the new system is indeed related to the situated theory of action.

Extensive notes and observations are kept by the researcher. Design documents, design alternatives, reflective notes, evidence about decisions taken, and any interview data with key personnel involved in the routine system are gathered during the re-design of the system.

The researcher finally reflects on her experience of applying the methodology and may modify the situated system design methodology. The modifications are likely to be in areas where the design methodology does not fully account for the practicalities of real routine systems and include fine-tuning the process of operationalising concepts in the situational design methodology. Following the fine-tuning the research team will also undertake an ontological evaluation of representation tools, the methodology itself and the resulting designs to ensure that the altered methodology is still situational in nature and that the designs are ontologically different from those constructed using a traditional design methodology. Where possible, designs for the original system are sought to confirm the difference in ontological status of the respective design documents. We also hope to use an independent systems analyst, bringing an experienced and dispassionate view to bear on decision-making specifically, to help validate that the design choices are indeed paradigmatically different from traditional design and development.

Case study sites will be selected that cover a diverse range of routine systems in a range of operational environments. This will ensure the methodology is adaptable and help to define any limits to its applicability.

7.2 Action Research

Following the several case studies (two are currently underway), we expect to undertake at least one action research cycle improving on a system where the existing system is seen to be ineffective. In this process the research team will work with a practitioner team to analyse, redesign and implement a new system including appropriate information technology elements. This will test the practicality of the methodology for design and also as a communication tool with practitioners during the design. Similar analysis will be applied at the end of this intervention as with the case studies to examine the claim that the situational design is indeed paradigmatically different from the inadequate starting system.

7.3 Progress

Two participatory case studies are underway. One is with a company that installs broadband, cable, and digital TV and the second focuses on the flow of out-patients through a chemotherapy ward in a large cancer hospital. It is expected that results for these cases will be available early in 2005. The action research site has yet to be been identified.

8. DISCUSSION AND CONCLUSIONS

In this paper we have described a program that is underway that refines an initial methodology for designing situational information systems into a fully-fledged robust methodology. Using traditional methodologies, designers decompose the world into object correlates for implementation in databases where information about the real world objects is held. A situational approach is likely to result in data about activities and situations being recorded so that action can be undertaken. The systems designed are likely to be radically different from those resulting from traditional methodologies.

The program, which is underway, uses participatory case studies (where routine systems are re-designed according to the method). In each case study a researcher is embedded in an existing system and re-designs it according to the situational design methodology. The methodology is successively refined and ‘operationalised’ to practical circumstances. Following the participatory case studies, at least one action research cycle will be undertaken to further refine and validate a mature methodology.

An initial methodology has been built from concepts found in the situational systems literature and refined through the completed pilot study. A company installing telecommunications infrastructure and a specialist cancer ward are two of the sites for the participatory case study phase of the research. It is expected that preliminary results will be available early in 2005. The methodology being refined in this project is likely to add a much deeper understanding to disparate attempts at designing information systems for difficult contexts involving repetitive routine activity.

The work is significant because although the situated theory of action has some influence on researchers working at the device or interface level it has not previously been applied at the level of whole socio-technical system design. If we are correct in our assertion that traditional information systems design methods are inappropriate to complex but largely routine work environments, the proposed methodology has great potential to uncover radically new and more effective information technology interventions in this important domain.

References

Agre, P. and D. Chapman (1987). Pengi: An Implementation of a Theory of Agency. The Sixth National Conference on Artificial Intelligence, Menlo Park, USA, Morgan Kaufman.

Agre, P. and I. Horswill (1992). Cultural Support for Improvisation. AAAI-92. The Tenth National Conference on Artificial Intelligence, Menlo Park, California, AAAI Press.

Agre, P. and I. Horswill (1997). "Lifeworld Analysis." Journal of Artificial Intelligence Research 6(1997): 111–145.

Brooks, R. A. (1986). "A Robust Layered Control System for a Mobile Robot." IEEE Journal of Robotics and Automation 2(1): 14-23.

Brooks, R. A. (1991). "Intelligence Without Representation." Artifical Intelligence 47(1-3): 139-159.

Clancey, W. J. (1997). Situated Cognition: On Human Knowledge and Computer Representations. Cambridge, U.K., Cambridge University Press.

Hammond, K., T. Converse, et al. (1995). "The Stabilisation of Environments." Artifical Intelligence 72 (1995): 305–327.

Hardy, J. and P. Drury (2001). Communication Process and Case Management Model of Care: Implications for IT development and implementation. Ninth National Health Informatics Conference, Canberra, ACT, HISA.

Hendriks-Jansen, H. (1996). Catching Ourselves in the Act: Situated Activity, Interactive Emergence, Evolution, and Human Thought. Cambridge, MA., MIT Press.

Horswill, I. (1995). "Analysis of Adaption and Environment." Artifical Intelligence 73(1-2): 1-30.

Johnston, R.B. (1995). "Making Manufacturing Practices Tacit: A Case Study of Computer Aided Production Management and Lean Production." Journal of the Operational Research Society 46 (10): 1174 - 1183.

Johnston, R. B. and M. Brennan (1996). "Planning or Organising: The Significance of Theories of Activity for the Management of Operations." OMEGA, International Journal of Management Science 24(4): 367-384.

Johnston, R. B. and S. K. Milton (2001). The Significance of Intentionality for the Design of Information Systems. Americas Conference on Information Systems, Boston, USA.

Johnston, R. B. and S. K. Milton (2002). "The Foundational Role for Theories of Agency in Understanding Information Systems Design." Australian Journal of Information Systems **2002**(December (Special Issue)): 40-49.

Johnston, R. B. and S. K. Milton (2002). The Foundational Role of Theories of Agency in Understanding Information Systems Design. Information Systems Foundations Workshop: Building a Theoretical Base, Australian National University.

Lederman, R., R. B. Johnston, et al. (2003). The Significance Of Routines For The Analysis And Design Of Information Systems: A Preliminary Study. 11th European Conference on Information Systems, Milan.

Lederman, R., S. K. Milton, et al. (2004). Identifying Theories of Agency in Information Systems. The Americas Conference on Information Systems, New York (forthcoming).

Suchman, L. A. (1987). Plans and Situated Action. Cambridge, UK, Cambridge University Press.

Wand, Y., D. E. Monarchi, et al. (1995). "Theoretical Foundations for Conceptual Modelling in Information Systems Development." Decision Support Systems 15 (1995): 285–304.

Wight, O. W. (1981). Manufacturing Resource Planning: MRP II. Essex Junction, VT., Oliver Wight Publications, Inc.