14. Lessons learned from manual systems: designing information systems based on the situational theory of agency

Simon K. Milton, ***Department of Information Systems, The University of Melbourne***
Robert B. Johnston, ***Department of Information Systems, The University of Melbourne***
Reeva M. Lederman, ***Department of Information Systems, The University of Melbourne***

Abstract

Information systems are part of purposeful socio-technical systems and consequently theories of agency may help in understanding them. Current systems analysis and design methodologies seem to have been influenced only by one particular theory of agency, which asserts that action results from deliberation upon an abstract representation of the world. Many disciplines have, however, discussed an alternative 'situational' theory of agency. There is currently no methodology that fully supports designing systems reflecting the situational theory of agency. The aim of this paper is to develop a first-cut of such a methodology based on concepts from the situational theory of agency, and is supplemented by our exploration of evolved manual situational systems. We intend to iteratively refine this methodology since we believe the situational theory of agency provides a better description of purposeful activity than the deliberative theory and is, therefore, a firmer foundation on which to build successful information systems, especially in pressured routine environments.

Introduction

Theories of agency discuss the possible ways of designing complex systems that display purposeful activity. Theories of agency 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 agency. The two theories have quite different modes of representation and action selection. In previous papers (Johnston and Milton, 2001; Johnston and Milton, 2002a; Lederman et al., 2003; Lederman 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 agency. However, existing approaches to computerised information system design and development are implicitly informed by the deliberative theory of agency. An approach different from present systems analysis and design methodologies is needed because many information systems fail in pressured routine environments,

where we would argue that the situational theory of agency provides a better description of purposeful activity.

Although it is possible to design information systems for pressured routine environments using traditional methodologies, many of these systems are ineffective, inefficient or not accepted by people using them. They work technically but fail, in the context in which they are placed, to support the routine work adequately. We have reason to believe that in order to achieve greater success and acceptance of information systems in routine environments, we need a methodology that explicitly acknowledges the situatedness of socio-technical systems and their components, of which human actors and technical artefacts are examples.

Our long-term aim[1] is to develop a situational information systems analysis and design methodology informed by the situational theory of agency. The first step is to establish an initial methodology to use in later stages of the research, which will employ action research. Consequently, the aim of this paper is to develop a first-cut of such a methodology based on concepts from the situational theory of agency and supplemented by our exploration of evolved manual situational systems. Although the methodology is intended for designing computerised systems, the specific focus of this paper is on learning lessons from existing manual situational systems so that the initial methodology, based on the situational theory of agency, can incorporate and generalise important features of situated systems that are currently in use and known to be effective.

The method we use in the paper is first to extract key concepts from the situational theory of agency as it is understood in robotics and discussed in other disciplines. Based on these concepts, we draw up a skeleton of a methodology for analysing systems. Following this, we examine several manual systems that have been either designed by users or evolved from practice, and that are both discussed in the literature and appear to be situational. We begin by establishing that the systems can be explained using the situational theory of agency. These systems are then used to understand how to apply concepts from the situational theory in practical systems before incorporating our experiences into the tentative methodology. We conclude by showing how we intend to refine the methodology.

Information systems design and theories of agency

We have argued previously (Johnston and Milton, 2002b) that existing information systems implicitly support the deliberative theory of agency. According to this theory (Johnston and Brennan, 1996), purposeful action proceeds by an agent building an abstract model or representation of the external objective world from sense data and then reasoning about this model to determine actions that will achieve goals. For example, in traditional transaction-based information systems, 'transactions' are gathered that represent changes in the world. Data models that correspond to the representation scheme are used to design operational databases that are affected by the transactions. In extreme cases, such as MRPII (Wight, 1981), application 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 by providing information about objects from reality using data gained through transactions. Decision support systems are good examples of this type of system.

[1] This program at The University of Melbourne is supported by an Australian Research Council Discovery Grant DP0451524.

In the past 30 years a number of methodologies have been developed to assist in designing such systems. These are often called information engineering methodologies (IEM), with Structured Systems Analysis and Design Methodology (SSADM), the British government standard, being a typical example. These design methodologies 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 et al., 1995). Given this focus on symbol/object representation, use of these methodologies encourages designs for socio-technical systems in which the information systems form the representational scheme which mimic the deliberative approach to agency.

On the other hand, disciplines other than information systems have considered an alternative approach called the situational theory of agency. 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 based on 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 relate to the agent's purposes (Agre and Chapman, 1987). 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') that obviate the need to plan (Agre and Chapman 1987). An affordance is a structural aspect of the environment that makes it possible for an agent to reach a desired situation 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 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 roles of representation in the situational theory. Situations are agent-centred and intention-laden. Representation of situations on the basis of a symbol/object isomorphism is neither possible nor necessary. An agent responds to being in a situation by taking an action. An agent needs to notice that it is in a situation and does so by sensing aspects of its environment. Consequently, aspects of situations are needed to fire situation-action responses. Agre and Chapman (1987) argue that the representational scheme is 'indexical' and 'functional' in nature. Indexical representations describe things relative to the agent and functional representations select things according to their relevance for the purposes of the agent or concern the activities in which the agent is engaged. Further, Agre and Chapman (1987) argue that to eliminate the computational complexity of action selection inherent in using aerial world models, indexical/functional representations of situation features that are relevant to the agent's goals are rebound 'on the fly'.

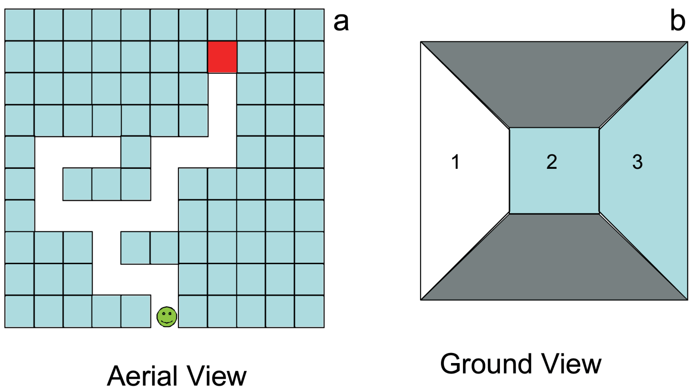
The reliance of the situational theory on indexical/functional rather than symbol/object representation shows it is built over different ontological categories: *situations, aspects* of situations, *actions, activities* (groups of situation/action pairs), *environmental structure,* and *environmental affordances*.

To illustrate the situational theory and how it differs from the deliberative theory, consider a rat searching for food in a connected maze without cycles (Figure 14.1 (a)). The rat could:

1. explore and build a mental model by *conceptually* lifting the roof off the maze; or
2. use a left-hand, wall-following rule to reach the food.

The first requires the rat to gather and hold a representation of the maze, as viewed from above and which includes all objects in the maze, before deducing a plan of action that is to be effected by it. The aerial view in Figure 14.1 (a) shows this (deliberative) view. The second is a situational approach, shown in the ground view in Figure 14.1 (b), where the rat notices a limited range of situations relevant to its activity and of which it becomes aware by sensing these aspects – the absence and presence of walls. To act, the rat only needs to be aware of the absence and presence of walls near it, and it is not interested in anything else in its environment. In this way representation is purely indexical (centred on the rat) and functional (for its acting).

Figure 14.1. The two views of 'Rat World'.



In the 'ground view' there are three aspects, numbered 1, 2 and 3. These three aspects completely determine the situation the rat is in, at least in relation to its seeking food. The rat will then select the action appropriate for the situation. All possible situations and their associated responses can be grouped into an activity (called 'seeking food in a maze').

As stated earlier, myopic-situated actions rely on environmental affordances for their efficacy. In this example, the environmental affordance is that the maze is singly connected and does not have cycles. It is the existence of this structural property of the maze that ensures that if the rat invokes the activity it will reliably reach food. This maze-navigating example illustrates the general point made by advocates of the situational theory (Agre and Horswill, 1992) and ecological theories of behaviour (Gibson, 1977; Schoggen, 1989) that environmental structures, or affordances, make a significant contribution to the production of goal-directed behaviour of real agents in real environments. As Agre and Horswill (1992) put it: 'it is almost as if these surroundings were an extension of one's mind'.

There are three ways in which a situational system is brought into being. First, a situational system could *evolve* so that agent actions and the effects of actions knit perfectly with the environment and situations to make activities reliable. Biological organisms are excellent examples of evolved situational systems. In many cases, such as social activities,

the activity and its environment may have *co-evolved*. Second, 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. Third, and this is the approach we propose for information systems, a system can be *designed* so that actions in response to situations 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. We assume that some level of iteration may be needed.

When an agent is confronted with an unknown situation, or when an existing activity is not reliable in an environment, there are at least three ways for the agent to respond. The most extreme response is to deliberate from first principles, much like the deliberative theory of agency. According to Heidegger, in his analysis of 'breakdown' (Dreyfus, 1991), an agent will resort to an ascending hierarchy of situated practices of repair before resorting to pure deliberation. For instance, an agent might first engage in another activity that is closely related to the failed routine activity but suited to a slightly different environment. An example of this would be using a different maze-solving routine. Alternatively, the agent could reason about the activities themselves without necessarily building a complete external world-model, which would amount to invoking a routine of problem solving.

We have used the situational theory of agency, as it is discussed in robotics and other disciplines, to determine the concepts central to an agent-centred situational system. 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 would make central the notions of an activity, situations that comprise activities, actions that are a reaction to situations, and aspects that allow situations to be detected. Also the situational theory would emphasise the importance of proper structuring of environments of action, which is largely ignored in the deliberative approach. Thus, a methodology for designing situational systems must:

1. *Identify the multiple agents and their specific environments that constitute the total situational system*. Situational systems of any complexity will consist of multiple interacting agents (human and technical) each situated in their own unique environment.
2. *Identify the activities that need to be undertaken by 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 is 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 a 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 that 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 provide aspects that resolve situations that prevent activities from becoming routine

The final methodology would consist of detailed documented guidelines for performing these steps together with appropriate representational analytical tools.

Thus far, the only experience in analysing situational systems in the literature is for designing robots and software agents. It has not been explicitly applied to socio-technical systems. However, there exist evolved routine work systems involving human actors and we are interested in examining their workings with respect to each of the theories of agency and drawing conclusions about how they work based on the examination. Should they be found to be consistent with the situational theory of agency, we may add depth to our understanding of the characteristics of situational systems. Consequently, in the following section we discuss three cases of evolved manual systems supporting routines. Manual systems are used in this paper because they are examples of effective situational systems. The design methodology for situational information systems assumes that agent environments, sensing mechanisms for situations, and actions may need to be designed from scratch and are thus 'blue sky'. Fine-tuning will be required where any unreliable activities are found: essentially 'tweaking' them to make them more effective. Fine-tuning will involve further moulding of the environment and improvement in sensing situations.

Learning from evolved manual systems

In this section we examine three user-designed routine systems in air traffic control, small-scale manufacturing (the Cash System), and large-scale lean manufacturing (the Kanban System). These systems have all been described in the literature and are interesting because their design does not fit traditional approaches to systems analysis and design. Although these are all manual systems, we do not intend our methodology to be applied purely to manual systems. But despite the fact that the systems we examine are manual, they can nevertheless give us important insights into how situated users view and represent their immediate situation (as opposed to the aerial view of the world used in the deliberative theory). In this section we examine each of the systems by exploring three things: what is being represented, what theory of agency is more likely to be useful in explaining its workings, and what features it has that may be helpful when designing systems to support similar cases.

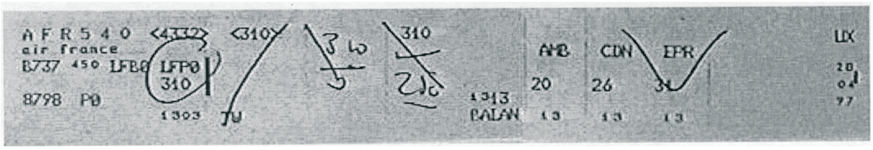
The structure of the section is as follows: in each subsection, we describe each system, discuss the approach to representation in the system, and classify the system as likely to be either situational or deliberative. We conclude the section with a discussion of what this tells us about designing situational systems.

Air traffic control: landing by the strips system

Airports have traditionally used a largely manual system for landing planes (Mackay et al., 1998). The system is still respected and used in many places, and in this sense is resilient. The system is routine and has an air traffic controller seated in front of a radar screen at an angled table of flight strips. The flight strips can be placed on the table in various configurations in relation to each other. Each airport has several air traffic controllers controlling different parts of the air space around the airport.

The activity of landing a flight begins with a printed-paper flight strip containing basic flight plan information. This strip is generated by computer or can be handwritten in the absence of a working computer system. Figure 14.2 shows a typical flight strip.

Figure 14.2. A flight strip describing Air France Flight 540 (Mackay, 1998, p. 322).



As an aircraft approaches an airport, a flight controller takes over control of its landing. When a new strip is generated, the controller's first task is to remove it from the printer and insert it into a strip holder. Strips are continually picked up and put down, reordered, grouped, offset, moved into columns, arranged and rearranged on the controller's table to denote different traffic conditions. The placement of the strips provides the controllers with information regarding action additional to that written on the strips. As the landing progresses, the flight passes from one controller to another by physical handover of the flight strip that, by its nature, is palpable for both controllers. Often controllers are side by side thus facilitating handover to another sector by structuring the area to help the activity.

Once a controller takes control of a flight strip, he gradually adds information to the typed strip (as seen in Figure 14.3). The markings allow controllers to look at a group of flight strips and quickly select the ones coming under their control and other information about how the activity is progressing. The layout of strips also gives a controller an immediate appreciation of the control environment (involving many flights) thus helping the controller to select the next action.

Figure 14.3. The strips being manipulated by an operator.

Each strip represents the activity of landing a specific flight and contains information important to landing the plane, not directly relating to the plane itself. In this way, the information on a strip is not tied to any specific object. Neither does each strip contain

all of the information required to land the flights that are under control. It is the structuring of the controller's environment using the strips that shows information beyond that which is on the strips themselves. For example, the way the strips are stacked in Figure 14.3 means something specific for the controllers and helps them to remember and reason about the flights they are landing. Handing over control of flights from one controller to another is achieved by passing strips and is facilitated by how the room is laid out, and such handovers seldom include verbal exchanges. The limited space where strips can be placed alerts the controller to busy situations because room for new strips is then hard to find. In these situations controllers will hold new strips in their hands. Controllers sometimes write their own strips when unusual things occur, relying on the convenience and flexibility of paper.

Analysing this system using the deliberative approach is not straightforward. No representation is tied to a specific object. Each strip is about landing a flight rather than the flight itself or the aeroplane. Together, the strips are about the activities of landing that are under the control of the controller. None of them describes a flight enough to say that they represent an object in the sense of the deliberative approach to modelling.

In contrast, this system is easily related to the situational theory of agency. The strips represent the activity of landing a plane and, together with other strips and their relative position, these are sufficient to enable a controller to appreciate the current situation and to select actions. This, in our view, is a more plausible explanation than one based on the deliberative theory of agency.

Small-scale efficient 'cottage' manufacturing: the Cash Compressor System

A small factory (Cash Engineering Research) manufactures air compressors and has built up a system for doing so over several years. The workers in the factory have played an active role in designing the system. Known as the Cash Compressor System, the system is for production control in a small factory of four staff manufacturing about 200 air compressors a year. The system has a whiteboard 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 whiteboard 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 hanging on shelves lining the walls. The main components of the system include a whiteboard 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 whiteboard. The parts for making the customer's compressor are checked for availability visually, and if need be, ordered on a one-off basis. The machine assembler then takes a machine base and begins construction, referring to the whiteboard 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 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 system: the availab-

ility and quantity of parts holdings are clearly seen on the shelf. The only recorded requirements-related information is in the reference to non-standard choices on the whiteboard.

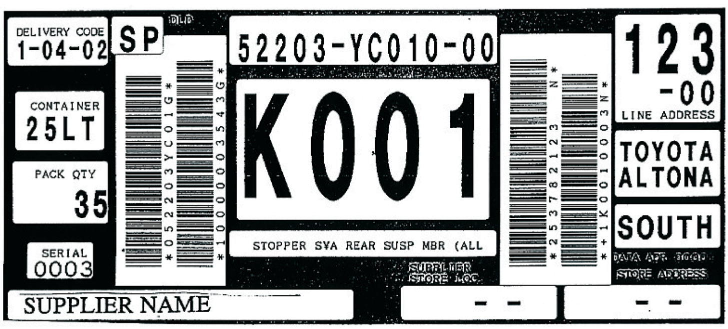
If this system were to be explained by the deliberative theory of agency, representation would include detailed information about each compressor being manufactured. This is not the case in the Cash System where very minimal information is kept explicitly on the whiteboard. No rules can be found to enable a worker to take the individual parts and assemble a compressor. Instead we see the next action being selected by the partly manufactured machine being presented to the worker. Only a limited range of choice is available to them. The worker knows what happens next because there is very little (often no) choice confronting them. When there is a choice, the whiteboard tells them the option to be selected based on the customer's desires.

The Cash System is a highly situational one where representation is almost absent. Action is selected by routinely acting on the partly manufactured machine based purely on the current status of the machine. In the Cash System, 'the world (is) its own model' (Brooks, 1991) in that the machine 'jigs' itself and parts are visible, obviating the need for stock data. Consequently, the current situation is found in the visible state of the stock on the shelf, the number of jobs on the floor, the condition of the partly manufactured compressors that are the jobs on the floor, and the markings on the whiteboard. Due to the careful design of the factory layout, all these are immediately visible to a worker. In addition, the use of a single small whiteboard allows the foreman to grasp the total production situation at a glance. The recorded information on the whiteboard is largely ephemeral (except for a small amount of recorded information for warranty purposes that is kept in a book). When a job is finished it is removed from the whiteboard and the new situation is revealed.

Large-scale lean manufacturing: the Kanban system

The Japanese Kanban system (Schonberger, 1987; Womack et al., 1990) is widely used in the automotive industry for the activity of replenishing parts for production. Kanban is the Japanese word for 'card' and the movement of cards in this system controls stock levels and replenishment activities. For each part there is a fixed size container. A Kanban has printed on it minimal information about the item it is used for, usually product ID, the primary supplier and the workstation where the part is used (see Figure 14.4). There are a fixed number of Kanbans in existence for each item and, except when *desired* manufactured capacity changes, they are neither created nor destroyed.

Figure 14.4. A typical Kanban card.



Imagine a container half-full of parts on a factory floor. The container has a Kanban attached to it. Goods are taken from the container, which is stored at the production workstation, until it is empty. The Kanban in the empty container is then placed on a Kanban board near the goods receiving area where it becomes a signal that the item needs replenishment. The board has hooks in supplier order. When placed on the board the Kanban becomes 'free'. The board has the Kanban system operation rules (Kanban rules) clearly displayed. When a supplier's truck arrives with shipments of items to deliver, the driver checks the Kanban board and takes the Kanbans on the relevant hook back to the supplier's site to authorise replenishment of these items next time around. When the items are subsequently supplied, the Kanbans are returned to the work stations, in the full containers, where they are used.

The deliberative theory of agency cannot relate at all to the Kanban system. The cards do not consistently correspond to anything specific in reality. When they reside with the parts they could be thought of as being a representation of these parts, although they have no system purpose in this state and they will later actually refer to a different group of parts. When they are free, they represent a stock shortage. When they are on the Kanban board they are an authority to re-supply the parts. There are no records of stock levels that we would expect to see in a deliberative approach.

Examining the system using the situational theory, a Kanban card represents part of the activity of maintaining stock of a specific item. All of the Kanbans, together with the rules by which they are used, provide simple ways of reasoning about stock. If many of the same type of Kanban appear at the board then an undersupply may be occurring or there may be trouble with the supplier's transport. An absence over a prolonged period indicates a delayed manufacturing process. In addition to simple, reactive rules for Kanban movement, the affordances of the physical nature of Kanban cards (they can neither be created nor destroyed and they cannot be in more than one place at a time) indirectly enforce all important replenishment business rules, in particular that there can only be a fixed number of parts in the system.

The Kanban is rebound over time from one full container to a different full container some time later. An interesting feature of this system that is the Kanban's meaning changes according to where it is. When it is travelling back to the supplier it functions as a request for an order from the manufacturer. When it is on the board it shows a shortage of a specific item.

Common features of the systems

Each of the systems outlined above has features in common and that mirror the features found described in situational systems literature: activities, situations, aspects of situations, environmental structure, and environmental affordances. We now examine each of these characteristics, highlighting the approaches each system uses. We emphasise interesting features that add practical depth to our understanding of the theoretical constructs.

All systems use tokens to represent activities. Physical strips in landing aircraft represent flights being landed. Rows on the whiteboard represent activities of making a compressor at Cash. Cards in the Kanban system represent the activity of replenishing goods. None of the tokens represent objects and properties in the way advocated in existing data modelling methodologies. An interesting feature of these manual systems is the use of positions of tokens to help actors in reasoning about activities. In the landing system, the relative position of the strips helps the controller to reason about all landings. Kanban cards on the board help operators to reason about goods shortages and priorities. The

importance of manipulation of concrete things in the environment for practical reasoning has been emphasised by writers on situated cognition (Lave, 1988; Clancey, 1997).

Tokens representing activities often have information about aspects of situations on them that show the actor the situation they are in. This is best illustrated in the landing system by the markings on strips. However, even in the landing system the position of strips relative to each other also shows aspects of situations. Similarly, in the Kanban system the presence or absence of tokens in various places reveals situations to human actors in the system. The Cash System partly shows aspects of situations on the whiteboard and partly in how much of the compressor has been completed. This is because the stage of manufacture of the compressor shows part of the situation to the worker. This parsimonious use of representation is quite consistent with the situated view, in which a small number of aspects are sufficient to trigger a situated action, but inconsistent with the deliberative approach.

Structuring the environment of systems is critical to situational activity because without it repeated actions would not reliably result in goal attainment. This is achieved in two ways. First, it constrains the possible new situations an actor experiences as a result of action and this reduces the cognitive burden of choosing alternatives. The structure of the maze is an example of this. Second, the environmental structure may help reasoning about activities. Often the palpability of tokens and their physical properties help deliver both benefits. In the landing system, a controller can position the strips relative to each other because of the slope and size of the table, thus enabling situation detection and reasoning about activities. In the Cash System, the partly manufactured machine, by being its own jig, only permits a restricted range of actions. The Kanban system limits the quantity of stock circulating by having only a limited number of cards. Workers can reason about delays in the activity of stock replenishment or in manufacturing by noticing prolonged absence or presence of Kanban cards in particular places. In addition, each of these systems requires considerable structuring of the broader environment of work to make these simple reactive systems work. For instance, the Cash factory is laid out so that the availability of all relevant part options is directly visible to the foreman when adding new records to the whiteboard. The need for work environment structuring, for instance the use of teams and production cells, for the successful implementation of Kanban is also emphasised in the *Just-In-Time* literature (Schonberger, 1987).

Tokens, or other parts of environments, also help actors to hand over situations to others. In the landing system, a controller can hand a strip to another controller because the controllers are often next to each other. In the Cash compressor system, a half-finished machine by its very state facilitates a worker in taking over the activity and situation from another worker.

In the flight landing system not only does the passing of a single strip pass the situation of a particular flight from one operator to another, but the visible arrangement of all strips is used to hand over the total flight situation at the change of shift (Mackay et al., 1998). Similarly, Kanban movements hand over a shortage situation between the multiple participating actors, while the arrangement on the Kanban board allows the total shortage situation to be seen by foremen.

Implications for a situational methodology

By examining the systems described above we can draw two groups of implications for a situational methodology. First, the examples exhibit many characteristics consistent with the situational theory of agency. Second, there are characteristics that emerge from

these systems that add to our understanding of the practical application of the situational theory. We discuss each of these below.

Each of the systems confirms activities, situations, actions, environmental structure and environmental affordances as important ontological categories for situational systems. Fundamentally, activities, not objects, are represented in these systems. Situations and aspects of situations are shown to actors so they can select actions or reason about their activities. Environments are structured and use affordances that increase the reliability of the goal of an activity being realised. The relationship between environmental structure and affordance is sometimes complex. This is seen in the Cash System where the machine is its own jig. The jig is designed so that the environment of the worker changes in such a way that precisely one situation is returned.

A characteristic emerging from the study is the extensive use of physical tokens (e.g. strips) to contain information about situations and activities and to facilitate reasoning. Tokens often represent different situations according to their physical relationship to other tokens, and their physicality aids reasoning about situations for human actors. The need for manipulation in situated reasoning is an important feature of these systems and cannot be ignored when designing a methodology for situational systems.

Physical tokens are also used to hand over situations to other actors involved in an activity. This is illustrated in the flight landing system where controllers routinely hand strips to other controllers. Successful handover is helped by the receiving controller having to physically handle the token.

In these systems tokens and other parts of an agent's environment play a critical role in representation. A human agent uses tokens in the environment to reason about activity and to notice situations. Tokens contain some, but not all, information about situations and activities. Often it is the relationship between tokens that completes the picture for an agent. Contrastingly, deliberative systems require a model of the world where objects and their properties are self-contained and correspond with objects in the human agent's environment.

The use of physical tokens requires that careful attention is given to the capabilities of computerised technology such as mobile devices when designing information systems. Poor selection of devices that do not deliver the required palpability, capacity for manipulation, or representational ability may place the success of the whole information system in danger. Further, environments of computerised parts of the information system must be carefully designed with these findings in mind.

Following our examination of manual situational systems, the methodology still consists of six steps. The details of specific steps, however, must be augmented with results from our analysis of the systems. These largely give insights into the implementation of Stage 6 in the method. First, in the manual systems explored, physical tokens are often employed by agents to represent parts of activities and contain information about situations. These are seen to be important for both situation recognition and for reasoning about action. Arguably, they do not reduce simply to the information displayed on them (Mackay et al., 1998). This gives an important insight into the unique character that the informational component of situational systems should possess. Although not all situational systems may need to employ the idea of physically manipulable tokens as the representational component of the system, it seems that it is a prudent approach to consider this possibility in conjunction with information and communication technology as a possible form that part of the information system might take. For instance, in a follow-up study of the manual air traffic control system described above, Mackay et. al. (1998)

trialled a computer-enhanced physical token-based substitute for the flight strips. Clearly new ICT technologies, such as mobile devices and ubiquitous computing can play a role here. Second, where relevant, the environment of the agents must be designed to aid situation handover between agents.

Discussion and conclusions

In this paper we have proposed an initial methodology for designing situational information systems. Using traditional methodologies, designers decompose the world into object correlates for implementation in databases where information about real world objects is held. A situational approach is, by contrast, 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. For example, it is highly unlikely that an IS designer trained in existing design methodologies would design a system with the simplicity and elegance of the Kanban system whereas an operator on the shop floor would probably see Kanbans as a logical system for controlling stock. This observation, which is in principle testable, dramatically highlights the gulf between information design theory and operations practice, which our methodology addresses. Furthermore, the use of Kanbans cannot be dismissed as merely a quaint or anachronistic manual system because it is now very widely used in the high-tech automotive manufacturing industry where it often replaces computerised systems based on the deliberative approach. Thus, this methodology has the potential to revolutionise information systems and, we expect, will lead to much more effective information systems in specific contexts.

We built the initial methodology by examining concepts from the situational systems literature and by building a tentative methodology based on these concepts. We then examined some existing (manual) situational systems found in the literature involving human actors to deepen our understanding of the characteristics of situational systems and thereby to strengthen the tentative methodology.

We have found, in examining human actors as part of evolved situational systems, that environmental structuring and the role of physical tokens in an actor's environment are critical to designing situational systems. Representation of situations and activities in an agent's environment helps situated reasoning and enables action with little deliberation. Physical tokens help agents to hand over situations and to solve problems. We also expect that, in computerised information systems, specific physical information and communications technology may be required to support physical tokens for human actors in these systems.

In future work, we intend using three action research cycles (Baskerville and Wood-Harper, 1996; Lau, 1999) to successively refine the methodology from here. In each cycle, an already implemented system in an organisation will be analysed and changed by applying the situational systems methodology. The methodology used in each cycle will be the output methodology of the previous cycle (or that emerging from the pilot cycle, if it is the first). The system selected in a specific cycle will be one that has been implemented using a traditional design and development methodology, involves routine work, and has been deemed to be ineffective.

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. Soft Systems Methodology, Human-computer Interfaces, and Ubiquitous Computing are all examples of other possible approaches but they lack uni-

fying theory. For the first time, there is prospect of a methodology for building situational information systems based on firm theoretical foundations.