Using Semiotics to Understand the Interplay Between People and Buildings

Penny Noy, Kecheng Liu and Derek Clements-Croome

University of Reading, United Kingdom

Corresponding email: p.a.noy@reading.ac.uk

SUMMARY

The purpose of this study is to examine the usefulness of semiotics in deepening our understanding of the interplay between people and buildings, and for providing the basis for personalizing intelligent buildings using intelligent software agents. The context is the increasing demand for improved working conditions at the same time as conserving energy. Semiotics, the study of signs, has a wide and varied scope. The study first decides relevant approaches; the two approaches used here are i) considering design as communication and ii) particular techniques from a branch dealing with organizations, Organizational Semiotics - *semantic* and *norm* analysis, including *ontology charting*. These methods are applied to the overall building scenario as well as the personalization system. Recommendations for designers are to use this approach to focus on designing to influence behaviour, and to use semantic and norm analysis to capture and embed norms explicitly.

INTRODUCTION

The overall aims of our work are increased well-being and energy conservation in indoor environments. In this context there are the following specific motivations:

- To encourage the saving of energy. The recent Stern Review [1] proposes three policies to address the threat of climate change: carbon pricing, innovation, increasing awareness and encouragement of energy saving. Each of these policies provides motivation for understanding better how people interact with building systems.
- To apply and investigate new technology impact, e.g. ambient intelligence, sensors.
- To understand more about individual responses to the environment, to be able to personalize the environment to improve health, general well-being and productivity.
- To protect and enhance people’s well-being indoors. As a global average, we now spend 80% of our time indoors [2] and people are living longer, increasing their interest in what habits and conditions are important short and long term.
- To create better models and predictions. Predictions from physical models often only account for a portion of actual performance, sometimes due to human factors.

Intelligent Buildings

A variety of definitions have been proposed for the term intelligent building, but for our purposes we consider two main approaches: one view based on the use of technology [3], and the other view as a broader concept based on a mirroring of human intelligence, where the building behaves intelligently in a holistic sense, within its environment [4]. Both these definitions are useful for this discussion: technology gives us new kinds of environments to investigate (how will people react to and use these new environments?); energy conservation and well-being are both part of sustainability (how can we encourage people to interact with intelligent buildings to improve sustainability?).

The specific context of our work is a project to personalize intelligent buildings, extending work of a number of research teams [3] [5] [6] [7] [8]. These systems use artificial intelligence and sensor networks to control environmental variables such as temperature, light, sound and air quality. The design of such systems provides requirements for the study of building/people interplay, though our perspective is not limited to these, because of the more general motivations described above. Figure 1 gives an overview of our proposed system which involves sensor networks sensing the environment and the people's actions, a multi-agent system representing the people, and controlling actuators. The horizontal part shows the sensors giving environmental and occupancy data to the agent system, which controls the actuators. The diagonal part shows the involvement of people: the occupants are represented by their individual preferences learnt from data collected by the personal agents and by direct input; the other stakeholders, such as the facilities manager and the owner, supply policy in the form of rules, or norms, relating to the allowed and desired behaviour of the personal agents. A key aspect of the design is the provision for occupants to be actively involved in the system operation [9].

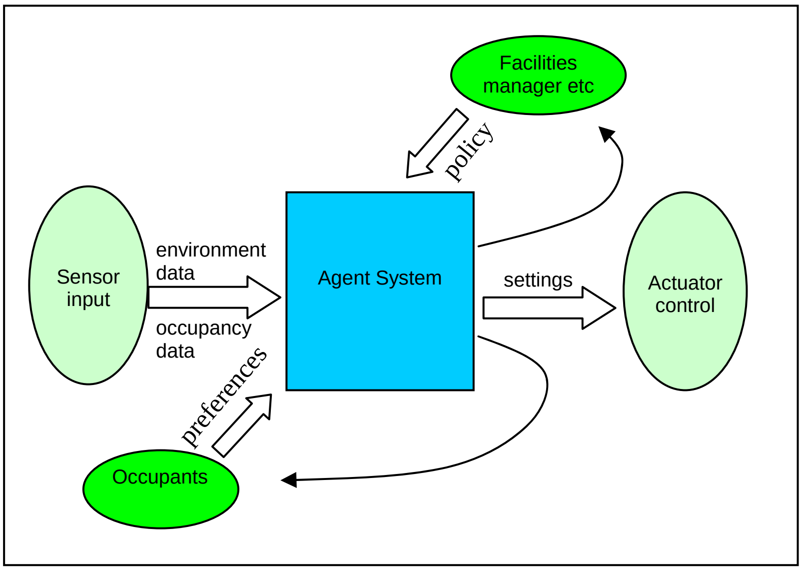

Figure 1. Overview of multi-agent system for control of the building environment

Semiotics

We propose using semiotics to deepen our understanding of the interplay between people and buildings, because semiotics, the study of signs, concerns how things are signified to us. What messages is the building giving us, visually, and through our other senses, directly (experientially) and indirectly (via information)? How do we know what we can do in a building? How do we understand how to do those things? How can buildings elicit responses from us? Semiotics, the study of signs, is a wide and varied field used across disciplines (art, advertising, linguistics and others) (for an introduction see e.g. [10]). A broad definition of semiotics is given by Eco: 'semiotics is concerned with everything that can be taken as a sign' ([11], p7, quoted in [10], p2). Thus, a sign is anything that can stand for something else – encompassing words, images, sounds, gestures and objects. Semiotics became a major approach to cultural studies in the late 1960s, but has not played such a role in computer science, though it is considered by some as providing a much needed part of knowledge representation [12], and of particular relevance for human computer interaction [13]. A development specific to the examination of communication and information in organizations, Organizational Semiotics (OS) [14] gives specific concepts and methods for examining organizations. As semiotics has been applied so widely, there are a variety of methods available. Within the context given above, and to obtain specific as well as general results, our objectives are to identify semiotic techniques that are appropriate for analyzing people/building interplay, and then apply the identified techniques.

METHODS

This section describes the semiotic approaches chosen for our context: *design as communication,* and specific techniques from OS.

Design as communication

A particular application of semiotics considers how the design communicates to the user. We can consider a large object, such as a building, or a small object such as a soap dish [15]. The message that an object gives us has intrinsic and extrinsic aspects. Intrinsic aspects concern the object itself, for instance whether it has a handle of some sort, inviting us to pick it up – 'by their look they invite certain actions' ([16] quoted in [17], p234). Extrinsic aspects concern such things as the context (e.g. where the soap dish is placed), and our own knowledge, deductive powers and experience. A consideration of the communication aspects of an object constitute good design, which may or may not include a conscious evaluation of the product as message. [17] discusses this issue in terms of 'stimulus-response capability', giving examples of door latches and numeric keypads, but also stressing the difficulty of making explicit the user's implicit knowledge and the need to watch what people do, not just listen to what they say. From a different perspective, [18] examines shopping malls, exposing their meaning of 'consume' on different levels. [19] examines how an organization's values, ethos, beliefs and behavioural codes are 'made visible' in the workplace.

Signs can be classified in different ways, which assists breaking down the message into its components. Pierce (1839-1914), one of the founders of semiotics, suggests three main forms of signs: i) symbol/symbolic: fundamentally arbitrary; ii) icon/iconic: resembles the signified; iii) index/indexical: indicates the sign in some way, so that the sign can be inferred (natural examples are smoke, thunder and footprints).

Organizational Semiotics

OS [14] provides specific methods for examining communication and information in organizations. A key concept in OS is that of *affordance*. An affordance refers to functionality (action that is *afforded*) that is provided by an environment to a responsible agent. By analyzing descriptions, problem statements, and other material, the agents, environments and affordances can be established; then a diagram can be drawn showing these relationships. Such a diagram is referred to as an ontology chart. Ontology charts can be used to gain insight into a problem and as a way of eliciting and representing user requirements. *Norms* can then be associated with affordances; these norms are the rules governing the normal use of the affordance.

RESULTS

In this section we examine the interplay from the point of view of design as communication on the macro (the overall building, building system) and micro (individual products such as radiators) levels, then apply semantic and norm analysis to the personalization system design.

Design as Communication

In recent years much effort has been expended upon creating more efficient products, including applying whole-life energy analysis, but less emphasis has been given to designing products that *encourage* energy-efficient *use*. In other words, the product as a *communication of how to reduce energy* is not considered. Designers are beginning to address this, for instance the Toyota 'EcoDrive Indicator' gives feedback to the driver – showing when they are driving in a fuel-efficient manner [21]. Since human use of products has so much impact on energy consumption, attention is beginning to focus on buildings (e.g. the 'Wattson', http://www.diykyoto.com/). Three ways that the product can encourage energy conservation have been identified by Lilley et al. [22]:

1. Intelligence. By observing the user's interaction and automatically adjusting to be more energy efficient. This can include decreasing irresponsible or anti-social behaviour.
2. Behaviour steering (scripts, affordances and constraints). By encouraging the user to use the product in a more energy efficient way through design.
3. Eco-feedback. Providing information to users to encourage pro-environmental behaviour.

For a wider view, specific to building control systems, consider these three together with the four manual and automatic control features given in [23], which also stresses the importance of designers making their 'intended operating strategies obvious, convenient and effective'.

If we consider buildings and building systems from the point of view of the messages they are giving us, we are asking not, do the spaces have the facility for X?, but, how is the facility for X indicated to the user? and how (assuming we want to encourage X) is the use of X (or a particular use of X) encouraged? When we enter a room, we see windows that can (maybe) be opened, a radiator that can be turned on etc. However, nothing tells us that we need to save energy, or how to save energy. We simply perceive (and expect) the freedom to use the objects as we want. So the system conveys to us the message that energy is free and available - the same message that has been driving society to use more and more energy.

Now consider the signs involved for an individual actuator, such as the thermostatic radiator valve in Figure 2, relating to existence, functionality, and how to operate.

Figure 2. Thermostatic Radiator Valve

- Firstly we can see that there is a control, the shiny silver top attracts us.
- It *invites* us to twist it by its shape. By handling it we can see that it twists clockwise and anti-clockwise. Anti-clockwise is iconic with opening.
- We can see numbers on the side and these go up when we turn the valve anti-clockwise, though they are on the side and so we can't see them very well. These suggest that the temperature will go up.
- There is a red band that gets wider as the valve is opened. This is iconic, red ≡ hot, so we think that opening ≡ hotter.

However, there is an ambiguity here. Does this mean that the radiator is hotter, or that the temperature of the air around the radiator is hotter? It seems that it should refer to the radiator as the valve is attached to the radiator. We are misled by the 'opening' of the valve - perhaps if it is partly opened, the radiator will be partly on? Of course, this is not the case, as this is a thermostatically controlled valve, so is sensing the temperature around the valve. This example shows that we need prior experience to read the conventions (e.g. twisting clockwise), but further understanding to fully control the device. Here the designers have included signs of functionality, but ambiguity remains without further knowledge.

Organizational Semiotics

Now we apply semantic and norm analysis techniques from OS, so that we can provide concrete specifications and, particularly, so that we: i) avoid loss of signification in moving toward automated systems (by analyzing the manual operation); ii) elicit and embed functionality and norms in automatic systems, so that they can be updated. Semantic analysis has four phases: problem definition, candidate affordance generation, candidate grouping and ontology charting [14]. A partial listing of semantic units extracted from the problem statement for the personalization system is shown in Table 1.

actuator action (of occupant) agents air quality (ventilation and CO2 levels) allowed alters amount (of clothing) ….	feedback goals group (of occupants) health and safety (agent) heart rate how good how well identification ….	personal agent personal profile personalizes policy preferences presence record repositories ….

Table 1. Partial listing of semantic units for the personalization system

From the semantic units, agents and affordances are identified, and then arranged as possible, or *candidate*, groupings. By combining these candidate groupings, a complete ontology chart can be drawn. Note that by following the procedure, the chart is derived exclusively from the requirements documents, so that it adopts the language and logic of the problem owners. The ontology chart for the proposed personalization system is too large to show here, so the manual situation is shown in Figure 3. A database structure can be generated from the ontology chart, for example in the form of a semantic temporal database (STDB) [14].

Norms govern the way individuals behave, think, judge and approach the world within a community [14]. Norms can be categorized in different ways; here we consider the category of behavioural norms, as most rules and regulations in organizations belong to this category. These concern what people must, may, and must not do, equivalent to the deontic operators ‘is obliged’, ‘is permitted’ and ‘is prohibited’. The general form of such a norm is

> **whenever** <context>
> **if** <condition>
> **then** <agent>
> **is** <deontic operator>
> **to** <action>

Applying this to the building system example:

> **whenever** a person occupies a room
> **if** the person is staying in the room for a while AND (is an employee of the organization responsible for the room OR has been invited by the organization)
> **then** the person
> **is** permitted
> **to** alter the room controls (window, actuators)

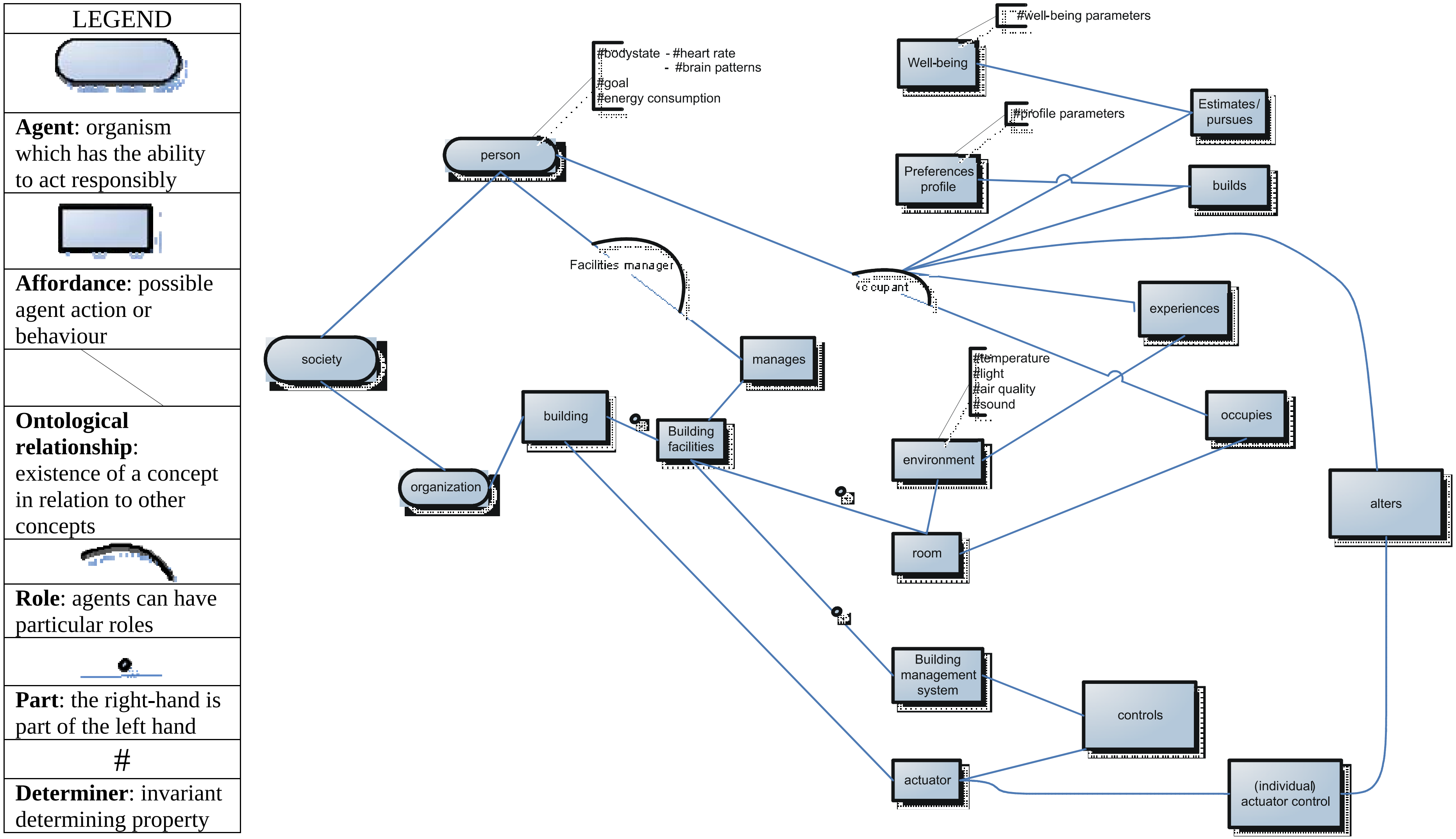

Figure 3. Ontology chart for manual control of environment

These norms can be kept computationally in a norm store, providing conditions and constraints for the system operations and being associated with the relevant affordances in the STDB. In this way, appropriate norms can be invoked whenever an action is requested. For the building example given above, the context is a person entering a room. If that person meets certain criteria, they are given permission to alter the room controls. The example can be translated into a norm specification language as follows:

```
whenever staying(person,room) AND (employs(organization,person) OR
invites(organization,person))
permitted to start alters(person,controls)
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This shows that this norm is connected with the affordances ‘staying’, ‘employs’, ‘invites’ and coupled with the affordance ‘alters’ in the STDB, and the inner brackets show each context and agent associated with each affordance. Every time there is an operation *`to start alters(person,controls)`*, this norm will be invoked. Thus, each norm is associated with patterns of activity described in the ontological chart, so that the requirements of the system can be defined in detail. The condition specification given here is only one of many possible, for instance this one could be changed and only specify the owner of the room to alter the room controls. Capturing this level of detail, having a way of storing it in the system, and the ability to access and change it later (as well as the possibility of discovering norms by observing behaviour) is of importance for autonomous systems which replace manual operations and need to be able to change and evolve at the same time as involving a variety of stakeholders.

DISCUSSION

The ‘design as message’ approach enables us to focus on the overall message of the design, as well as affordances and constraints. Currently little is being done to convey energy conservation messages within the product itself. We are relying on general education, but this is inadequate, especially since there is actually a constant rise in electricity consumption due to electrical goods. The energy demand in the home from acquisition of more electrical equipment has increased by 70% between 1970 and 2001 [24]. The radiator thermostat example suggests a means of decomposing the signage of products, and can be applied to other levels, such as the overall system and the software application. Semantic analysis provides a different approach for the elicitation, verification and recording of requirements, which can be used for the design phase, as well as the embedding of behaviour norms. This will help to see whether the product conveys the message the designer wanted, as well as measuring usability and functionality [13]. Norm analysis gives a form for capturing behaviour as rules and thus provides an explicit representation for computational use.

This initial study shows that semiotic techniques are promising and indicates the value of furthering the work. Specific recommendations are to:

- Apply ‘design as communication’ perspective on different system levels.
- Use ontology charts to capture the signification from the start.
- Use norm embedding to enter rules explicitly and enable storage and updating.

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