Highlighting the affordances of designs
Mutual realities and vicarious environments

Christopher Tweed
School of Architecture, The Queen's University of Belfast

Key words: affordances, human-environment interaction, design evaluation, agents

Abstract: Computer-aided evaluation of predicted design performance is an enduring theme within CAAD research and practice. However, most evaluative systems address aspects of design that are readily amenable to formal or quantitative treatments. Analyses of how people use and interact with designs rarely progress beyond a narrow functionalism, in which 'the user' figures as a type with poorly defined needs and characteristics. This paper outlines a theory of actor-environment interaction based on Gibson's notion of affordance as a precursor to exploring how computers can be used to highlight the affordances of designs. Two simple prototypes are described. The main conclusion is that while computers are unlikely to be able to detect affordances, they can generate and present information in ways that will enable human designers to appreciate more fully the possible implications of their designs for a broader range of potential occupants.

1. INTRODUCTION

Computer-aided evaluation of predicted design performance is an enduring theme within CAAD research and practice. However, most evaluative systems address aspects of design that are readily amenable to numerical treatments, such as energy modelling, structural and cost analyses and lighting design. When CAAD *is* used to explore design solutions it is generally to visualise 3d form. Existing applications, therefore, prioritise quantifiable and visible aspects of buildings over others. Precisely because these types of CAAD tools are widespread, there is a tendency for designs to be assessed mainly, or only, against a limited set of parameters. This leads to a form of reductionism in which buildings are viewed primarily as formal compositions, energy consumers, structural systems or 3d sculptural objects. But, as has been argued elsewhere (Tweed, 1997), the prioritisation of the visual, to the neglect of non-visible aspects of design, leads to an impoverished architecture. The most revered buildings are generally those which engage all of our senses, as well as our intellect. If CAAD is to make significant contributions to raising the quality of design then it will have to embrace a wider range of concerns, including the kind of experiences designs offer their eventual occupants.

Designers tend to treat the users of their designs in stereotypical fashion—the user is a single 'type' whose characteristics are rarely fleshed out in any detail. As a result, designs often ignore the special needs of many potential occupants, e.g. children, mothers, the elderly and disabled. Increasing emphasis on the need to provide inclusive environments, suggests we need to account for a much wider range of occupants than we do now. Hence, there is considerable advantage in developing CAAD tools which will allow designers to assess their designs from the viewpoints of different potential users or occupants.

The purpose of this paper is to suggest ways in which computers might be able to highlight the use-value of designs for a variety of different occupants. The research attends to their heterogeneous needs and how these might be satisfied or denied by a design. The intention is to use CAAD to explore fundamental human-environment interactions. The paper begins by outlining theories, emerging from ecological psychology and anthropology, about how people interact with their surroundings. The discussion then considers how these theories might be applied in a computational environment, illustrated by examples of prototype applications with different levels of computational ambition. Finally, the paper presents a discussion of issues surrounding the application of the theory of affordances to CAAD, in particular in the knowledge each type of system requires of the design and its possible occupants.

2. HUMAN-ENVIRONMENT RELATIONS

2.1 Functionalism in architecture and CAAD

Buildings are generally assumed to have well-defined functional properties which can be treated and assessed independently of actual users. The origins of this view can be traced back to the early part of the 20th century when functionalism emerged as a central plank of the modernist agenda. In functionalism, architecture is primarily a matter of accommodating the functions that are prescribed for it. Architecture must work efficiently by conforming to ideal, scientifically generated and tested user requirements. Le Corbusier's definition of the house as a "machine for living in" and Louis Sullivan's maxim "form follows function" epitomise the functionalist approach. While specific architectural devices of functionalism are many and varied, they often share a preference for parsimonious design, with unadorned and clearly expressed structure and fabrication methods (Rowe, 1987). Spatial organisation is derived from a well-defined programme of uses and activities. Designers sought optimal spatial configurations for accommodating human activities. Strict hierarchies of uses and elements were contrived to categorise prominent and subordinate areas of activity. These were often ergonometrically determined and, because of the emphasis on machine efficiency, were usually planned to satisfy minimum space standards. Designing circulation within buildings was often reduced to the problem of maximising the proximity of use-functions to minimise travel distances. Planning of buildings centred on idealised descriptions of the occupants and their activities, such as eating, sleeping, cooking, washing, and bathing. Spaces dedicated to these activities were designed as distinct (and often, separate) activity areas.

In the second half of the last century it became clear that the prevailing theories of function could not account for the richness of everyday interactions between people and their designed environments. So, whilst functionalism had, and still has, a core intention of meeting users' practical requirements, the notion of 'the user,' and his or her interaction with actual buildings was narrow. Plying a strongly behaviourist line, functionalism tends to treat occupants of its buildings as simple biological organisms with highly predictable behaviour to match.

Many contemporary designers still adhere to some form of functionalism. It is not surprising, therefore, to discover that recently completed empirical studies of work environments show that the designs of even greatly admired, contemporary architects often ignore how people interact with their surroundings (Koffka, 2000). CAAD, with its penchant for "rational" (functionally systematic) methods of design is both strongly influenced by functionalism and furthers its application.

2.2 Direct perception and affordances

In *The Ecological Approach to Visual Perception*, J.J. Gibson (1979) argues that our understanding of the world, as acquired through perception, is the result of our continuing engagement with the world. Opposing the prevailing cognitivist orthodoxy, Gibson claims that perception is not a matter of a mind processing the 'raw data' supplied by the body's sensory apparatus, but is a single act in which the human being (body and mind) directly perceives its environment. Perception is not, therefore, a two-stage process of sensing followed by interpretation, but is the direct apprehension of what an environment offers, or *affords*. The pairing of an organism with an environment results in a more or less unique set of *affordances*. In general terms, an affordance is what an environment offers an organism, for good or for ill. Thus, we can say that trees afford climbing for squirrels, but not for dogs. An affordance only emerges through the pairing of an organism and an environment. Thus, "[a]n affordance is neither an objective property nor a subjective property. It is both. An affordance cuts across the subjective-objective dichotomy and in doing so highlights the inadequacy of this dualistic thinking. It is equally a fact of the environment and a fact of nature. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer." (Gibson, 1979, 129).

Affordances, therefore, are the results of, and emerge from, interactions between people and their environments. For a given environment, they differ depending on the individual, his or her circumstances and the characteristics of the general situation; they recognise the uniqueness of human interaction rather than presupposing objective functions for an environment.

Gibson is critical of the fact that a theory of affordances is lacking from architecture: "…a glass wall affords seeing through but not walking through, whereas a cloth curtain affords going through but not seeing through. Architects and designers know such facts, but they lack a theory of affordances to encompass them in a system." (Gibson, 1979, 137).

Unfortunately Gibson provides little more than a sketch of what a theory of affordances might look like. More recently, Ingold (1992) has begun to flesh out Gibson's ideas in greater detail, and introduces the term *effectivities* to denote the physical and psychological properties of individuals. Effectivities define what an organism is capable of doing—for example, in physiological terms, its mobility—in a given environment. Effectivities of organisms and properties of different environments combine to define what an environment affords a given organism. For Ingold, humans are like any other organism, with one important difference: people design. Humans are the authors of a large part of their environments, as well as being 'users.' Ingold, however, is adamant that 'culture' has little or no place in accounting for which affordances 'show up' for different organisms.

Dreyfus (1996), however, emphasises the cultural component with reference to the philosophy of Merleau-Ponty (1962). For him, an affordance is seen as a culturally conditioned response to an artefact, such as a chair. Dreyfus argues that a chair affords sitting on because we have the kind of bodies that bend at the back of the knee and because sitting is a culturally defined norm in many situations. Many, rather than all, because there are occasions when sitting in a chair may not be culturally or socially sanctioned—in pre-westernised Japan, or in the presence of certain others with different social standing.

As Dreyfus's account suggests, we might also need to include culturally defined skills as one of what Ingold calls an organism's effectivities: "J.J. Gibson, like Merleau-Ponty, sees that characteristics of the human world, e.g. what affords walking on, squeezing through, reaching, etc. are correlative with our bodily capacities and acquired skills, but he then goes on … to add that mail boxes afford mailing letters. … Affords-mailing-letters is clearly not a cross-cultural phenomenon based solely on body structure, nor a body structure plus a skill all normal human beings acquire. It is an affordance that comes from experience with mail boxes and the acquisition of letter-mailing skills. The cultural world is thus also correlative with our body; this time with our acquired cultural skills." (Dreyfus, 1996).

2.3 Affordances and design

Within design, we find some ideas which come close to capturing the notion of affordance. As part of the 'populist' reaction against extreme functionalism, Alexander's 'pattern language' attempts to understand the relation between bodily capabilities and preferences, cultural settings and designs (Alexander et al, 1977). Alexander's work is revered and reviled in equal measures by the architectural community. The almost complete subordination of classical formalisms to practical and symbolic concerns has alienated many architects. Sadly, the underlying concern with offering enriching and interesting experiences for the occupants—which is at the heart of *A Pattern Language*—is thrown out along with the populist approach. For this research, the most important contribution of Alexander's work is the way in which it points up issues of occupancy which are rarely, if ever, discussed, such as the need for shelving at a certain height, or the social interactions which different degrees of enclosure permit and encourage. Ultimately, however, the patterns are too prescriptive and rely on too much uniformity of purpose, need and desire in the imagined occupants.

The lack of attention given to aesthetic and formal considerations in Alexander's work may be remedied by absorbing aesthetics within an extended concept of affordance. There is no reason why we cannot speak of a building affording delight, as well as commodity and firmness. Papanek (1985), for example, broadened the notion of function to embrace aesthetics in what he called the 'function complex.' His aim was to dissolve the harsh distinction between utility and aesthetic pleasure. He quotes his students as asking "'Should I design it to be functional … or to be aesthetically pleasing?' … 'Do you want it to look good, or to work?'" (Papanek, 1985, 19). Whether we can ever successfully embody this way of thinking within CAAD remains to be seen.

3. EFFECTIVITIES

Effectivities are those characteristics of individuals that decide which affordances emerge from interactions between occupants and environments. *Table 1* lists some of effectivities required of an actor and the corresponding properties of a door needed to confirm the affordance of passage. Most design concentrates on physical effectivities, for which standard ergonomic and anthropometric design guides are available. The extent to which these apply will depend on how closely the occupants conform to statistically defined norms.

Table 1. Some effectivities required for the affordance of passing through a door.

Category	**Issue**	**Effectivity**	**Door property**
Physical	Is the occupant physically capable of passing through the door?	Dimensions; mobility; dexterity; physical strength needed to open and hold door.	Dimensions of door and approach; operability of door equipment.
Psychological	Is the actor pre-disposed to pass through the door?	Personality; mood; need of passage; knowledge of, and attitude towards, what lies on the other side of the door.	Symbolism.
Social	Is it socially acceptable for this actor to open/pass through the door?	Social or organisational standing; right to use door and connected space.	Symbolism and signage; locking.
Cultural	Is the actor aware of the practices surrounding the use of doors?	Familiarity with door-using culture.	Transparency of operation.

In this broad view, it would be necessary for all of these effectivities to be positive for the affordance of passage to emerge from a specific actor-environment interaction. And the list is not exhaustive. Even for this very simple example, the array of effectivities which needs to be considered to confirm or deny the affordance is huge. So, the example alerts us to the complexity of interactions and to the difficulty in identifying affordances in designs. We shall return to this topic when we consider the computability of affordance recognition.

Specialised areas of design offer detailed consideration of effectivities, particularly where they are considered to depart from societal norms, such as for those with physical or cognitive disabilities. In gerontology, terms such as functional performance and competency are used to describe how well an individual is able to carry out everyday activities. Design guidance for frail elderly emphasises the need to consider actor-environment interaction in much greater detail (Schwarz and Brent, 1999).

3.1 When is a door not a door?

We conclude the first part of the paper by considering a common feature of all buildings—the door—and the affordances it offers different actors.

At the most abstract level a door provides a variable opening between two spaces. To afford passage, a door must open. When closed, the door will be expected to offer varying degrees of resistance to flows between either space. A closed door between outside and inside would normally be expected to prevent people from passing in either direction and stop the penetration of wind and rain from outside to inside. Less predictably, the door may or may not allow light to pass in either direction. Door glazing, therefore, although common, is not necessarily a universal feature of doors. Not all doors afford seeing-through. Even when glazing is used, the amount and type may vary enormously.

When open, a door will present an opening with shape and dimensions which will determine what kind of objects can pass through it. With most doors, the opening can vary from a thin vertical strip to wide open. But perhaps just as important, the immediate environment of the door will also determine what and how things can pass through its opening. Numerous comic situations have been created by the difficulty in moving furniture through doorways. To reveal a passage, the door must move and take up a new position. Fledgling designers are mostly aware of the opening behaviour of doors, certainly of those that open conventionally, by swinging on hinges, but still forget that doors are dynamic objects and that opening is a process. Many forget that a sliding door has to slide somewhere on a track and that, with the exception of concertina and folding varieties, the shape and size of the door will remain constant throughout the opening process.

Moving to a lower level of analysis, we turn our attention to the way in which a door is opened. To ensure that the door stays closed when required to do so, most will have a latch which engages with a striking plate on the frame. To open the door requires that we retract the latch from the plate by activating a lever or turning a knob. The obstacles to retracting the lever are potentially numerous: the handle is missing or falls off; the lever mechanism of the hinges have seized because of corrosion; the door is locked; or the handle cannot be reached. This last obstacle raises the question of how, and for whom, a handle becomes inaccessible. A handle placed 1 metre above floor level will be accessible to most ambulant adults, but not necessarily to a 3-year old child.

In summary, a given door affords passage for a range of different people, organisms, and things; a potential barrier to precipitation, moisture, light, sound, gaze, air movement; and, with a suitable locking mechanism, control over the movement of people and things between the connected spaces. It should be noted that it is impossible to exhaustively identify the affordances of any door, because new affordances arise from encounters with new actors.

4. BEING IN THE DESIGN

The large number and sheer complexity of factors which need to be considered to grasp the possible interactions between different occupants and a future building makes the identification of affordances a daunting task. It poses some interesting research questions: what is the most fruitful way for us to understand what a design offers different groups of users? Can computers assist in this task? And, if so, how?

Computers are already able to tell us (more or less accurately) how much a design will cost, how much energy it will use, what sort of environment it will offer and what it will look like from an infinite range of viewpoints. These capabilities, in the broadest sense, can inform the identification of affordances. We can legitimately ask, for example, does a building afford energy conservation? In this paper, however, the crucial question is can we extend our analyses to gain some idea of what it will be like to *inhabit* the design?

It should be obvious from the above that the number of potential affordances in a design is very large, and quite possibly infinite. To attempt to identify everything (for good or ill) a design affords is neither possible nor desirable. It will be necessary to highlight those which seem most important for different actors.

We begin by examining how existing methods of simulating experience measure up to the theories described above.

4.1 Activity modelling

Most activity modelling is concerned with the movement of people around buildings, for example, in the event of a fire or other emergency. Activity modelling, therefore, often implies a particular theory of how people behave in buildings and of their practical needs. A crucial difference between activity modelling and the approach adopted by this research is the distinction between activities and practices.

The activity of sitting spawns many different practices, depending on the cultural and social context. Washing oneself is an activity with reasonably well-defined spatial requirements, for different configurations and types of washing devices (showers, baths, lavatory basins), but bathing, as a set of practices, admits other concerns, such as degree of privacy (acoustic as well as visual), the implied connections to drying oneself and the nearness of drying towels etc. Anthropometric data on heights for shower outlets, shower trays, baths, and lavatory basins are necessary, but not sufficient, to describe the practices of bathing, washing and drying.

To return to our earlier example, if we consider the activities doors support, in isolation from the effectivities of those who interact with doors, we exclude the practices that grow up around people and doors. The difference is best illustrated between the way in which people expect things to be used—their 'proper' function—and the way in which they are actually used, by different people. Fire doors are a good example. When is a fire door not a fire door? Precisely when it is wedged open by the occupants of the building. It is this gap between intended function and actual use that we are trying to address in this research.

4.2 Virtual environments

It is entirely feasible that in the future it may be possible to configure virtual environments to simulate the effectivities of different users, and there is already some progress on this front, for example, in a test rig developed at Strathclyde to simulate movement through a building in a virtual wheelchair. But until problems with nausea and perceptual realism are solved, or systems become less expensive, virtual worlds will remain highly specialised, beyond the reach of most practising designers. Rather than virtual realities or environments, we need design tools which support the development of mutual realities and provide vicarious environments through which designers can gain a deeper understanding of a range of viewpoints on their designs.

5. HIGHLIGHTING THE AFFORDANCES OF DESIGNS

The remainder of the paper describes work carried out by the author on two prototypes which have the broad aim of highlighting issues surrounding the inhabiting of designs.

5.1 The “Walkies” demonstrator

The ‘crit’ is a staple of architectural education, during which instructors question students about all aspects of their design, including its suitability for occupation by different people. Many of the questions are about what it would be like for a user to experience the eventual building. To promote a greater sense of vicarious involvement with designs and to direct attention to specific problems, we developed a simple prototype display system which allows representations of different users to be moved around plan drawings. This was largely an attempt to animate the diagrams produced in paper design guides.

The ‘situated sprite’ is the most basic technique for directing attention to possible affordances of designs. The sprite is a graphical representation of different types of occupant. A range of sprites has been designed for use on plan drawings, as plan views of the types of occupant they represent. One sprite, for example, is a plan view of a person in a wheelchair; another is of a person pushing a child’s ‘buggy.’

A demonstrator was constructed using Macromedia *Director* which allows the user to import a plan drawing as a backdrop to the *Director* ‘stage.’ During a crit, an instructor can ‘pick up’ an appropriate sprite and use this to ‘walk’ around the plan—hence the system moniker of “Walkies.” This very simple system provides little sophistication, and does little other than automatically orient the actor to the direction of cursor movement. *Figure 1* shows a series of screenshots showing the movement of an actor around a furniture arrangement. The main aim in developing this system was to provide a focus for dialogue between designers and potential occupants of the resulting design (Tweed and Woolley, 1992).

The system’s knowledge of the design is minimal. It requires only the ability to import a bitmap at a given scale. The system is flexible, but limited. It relies on its users to make the links between the represented actor and the depicted design.

This system, though extremely easy to implement, is useful in drawing attention to potential problems in designs merely by suggesting the inhabiting of a design by different actors. We must be careful not to complicate design tools simply because they do not use the latest or most sophisticated technologies. However, it is clear from these early experiments that there is further potential in this approach.

Whilst technically trivial, the utility of merely drawing attention to the presence of different types of users in a design should not be underestimated. Anthropometrically accurate sprites, used consistently during design tutorials, serve as a focus for the ensuing discussion surrounding the experience of a design by different user groups.

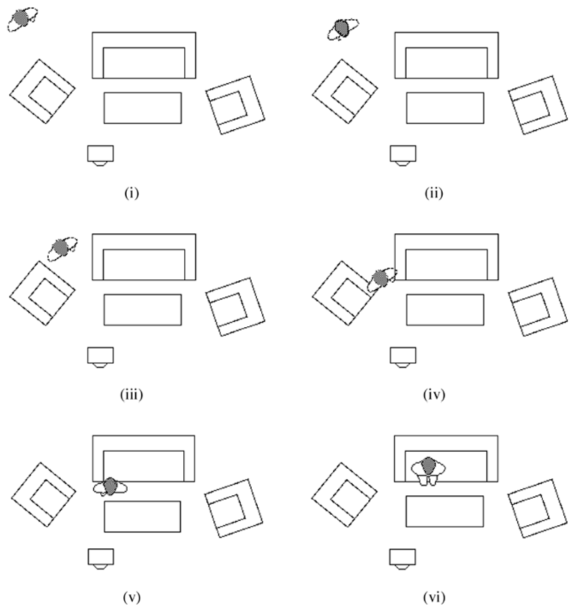

Figure 1. An early exploration of movement in a space.

Perhaps it is sufficient for computers to merely remind designers that different types of user are likely to use their buildings. Rather than aim for a highly ambitious and complex automated affordance evaluator, it may be just as fruitful to suggest issues that need to be addressed *by users* to evaluate a design proposal.

6. THE *ADEPT* SYSTEM

Although a very modest step, the "walkies" program has inspired us to seek further ways of conveying the latent possibilities of experience in a design for different actors. This is an ambitious aim, which will take a long time to realise. It is a programme of research rather than a single project. We are developing the *ADEPT* (Affordances of Designs Evaluation and Presentation Toolset) system as an expandable set of computer-based tools which will highlight different aspects of a design and so allow designers to view their efforts from a range of different concerns. It consists, at present, of a series of exploratory studies rather than useable prototypes. Two types of study are being investigated. The first addresses accessibility; whereas the second examines ways of displaying dynamic sensory fields centred on different types of actor.

6.1 Development environment

The development environment for both consists of the *ArchiCAD 6.0* drafting, modelling and rendering system, the Applications Programming Interface (API) for *ArchiCAD*, and the *CodeWarrior* Integrated Development Environment (IDE). *ArchiCAD* is a comprehensive architectural modeller which offers the user a range of parameterised building elements with which to describe their designs. In addition to conventional elements such as walls, windows, doors, roofs, and slabs, the system allows users to define their own parameterised objects as library parts. *ArchiCAD* comes with its own library and there are also several extensive third party libraries available. 2d graphical primitives are defined too. As is now commonplace in most CAD systems, *ArchiCAD* provides tools and commands to create, define and manage model layers, element materials and their properties, 3d views, and animations. One of the most useful additions to recent versions is the zone. Zones are primarily 2d area fills which can be manually or automatically defined. A zone, however, can have non-graphical information attached to it.

The *ArchiCAD* API allows the programmer to interrogate and change the element and attributes databases via 'add-on' modules. These add-on modules are accessed through items added to *ArchiCAD's* menus and tool palettes. Add-ons can modify existing or create new elements and attributes (e.g. layers). The programmer can define handlers for a set of events generated by *ArchiCAD*.

For our purposes, the only major drawback is that with the current API there is no mechanism for intercepting low-level events such as mouse clicks or information such as the current position of the cursor. Add-ons can only be activated by specific user requests. This prevents us from providing a display within *ArchiCAD* which is automatically updated in real-time as a sprite is moved around the plan. We are considering two different solutions to this problem. First, it may be necessary for add-on modules to provide and control their own windows to display information. This would require the add-on module to replicate the graphical functions which the CAAD system already provides. The other, less attractive option is to abandon direct interaction with *ArchiCAD* and export models to a dedicated application.

6.2 Occupancy and accessibility

Perhaps the simplest affordance we can address using CAAD is accessibility. We have developed an exploratory prototype to examine ways in which the accessibility of a design can be assessed quickly and easily. In its present form, the prototype analyses the geometry of a plan and identifies the obstacles it presents for different users. To do this, potential users must be represented in the CAAD system with the information needed to determine which parts of the design represent an obstacle.

As shown in *Figure 2*, the designer places a potential actor (chosen from a range of available library parts) on the plan of the building, selects this actor and then, via a menu command, asks *ADEPT* to show accessibility for that actor from that point. The system extracts from the actor's description basic information, such as the width of the actor and compares this effectivity with properties of the design.

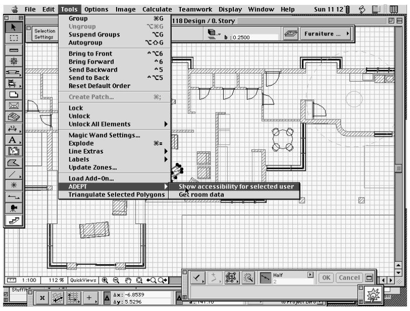

Figure 2. the accessibility menu command.

Figure 3 shows the resulting accessibility zone for the selected actor superimposed on the plan view. For now, the accessibility function takes no account of furniture arrangements and assumes that an actor can move freely within the spaces indicated. Accessibility is determined solely from the actor's width and available door openings.

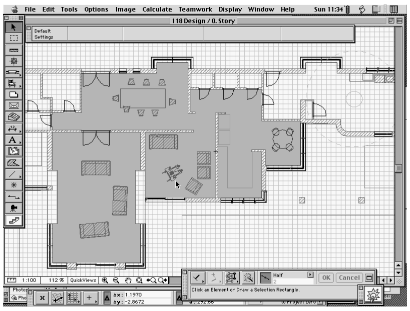

Figure 3. the resulting accessibility zone.

This relatively simple example raises important points for discussion. If it is known in advance that this house will be occupied by a person in a wheelchair then much of the design discussion will probably centre on relevant issues, such as accessibility. But if, as in this case, there has been no mention of mobility then tools such as this could operate as a simple check, requiring little effort on the part of the designer, but highlighting some of the problems which might occur.

6.3 Describing dynamic perceptual environments

Many basic affordances depend on the changing physical environmental conditions in a space and are tied to thermal, visual and auditory comfort. We have begun to examine integrating dynamic thermal, auditory and visual analyses with *ArchiCAD* to provide real-time display of sensory fields surrounding an actor. This work is in its early stages. *Figure 4* shows a mock-up of the kind of display from this type of analysis. For now, this is limited to displaying the visual field for a given actor with a given orientation. The intention is that several sensory fields will be displayed simultaneously, so that a designer can see the intersections and overlaps between lighting, thermal and acoustic environments. For the thermal environment, it is proposed to use the author's existing thermal modelling package to show the conditions surrounding the actor, including the radiative components of heat exchange between the actor and room surfaces. Convective conditions pose greater problems as they will require the integration of a computational fluid dynamics (CFD) package. However, if calculations are carried out on a room-by-room basis this should be possible within real-time.

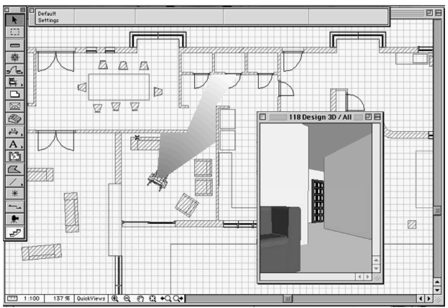

Figure 4. highlighting the visual field.

6.4 Discussion

The *Walkies* demonstrator represents a low-ambition, low-functionality, highly flexible critiquing system. It 'knows' nothing about the design or occupants it displays. It requires that its operators do most of the work. This is CAAD operating primarily as a medium rather than as a tool. In contrast, the *ADEPT* system requires knowledge about the building in a particular form (as an *ArchiCAD* model.) In both cases, the salient point is that CAAD systems always exist in some context, and a significant part of their context is social (Tweed, 1998).

The principal advantage of *ADEPT* is that it draws attention to important features of designs which would otherwise remain tacit, and beyond critique. The prototypes are at a very early stage of development and there are technical and conceptual issues to be overcome to progress further. Specifically, any form of automated affordance detection seems highly unlikely. However, even the limited experience in using these prototypes suggests that we can do something useful with CAAD to broaden its scope and thereby address wider issues in design.

7. CONCLUSIONS

The highlighting of affordances is likely to remain a strictly human capability, but computers can assist designers by presenting relevant information about the environment and its inhabitants in ways that make it easier to consider their interactions. The task of highlighting affordances, therefore, is not one that requires sophisticated algorithmic treatment, but rather one of information design. Simply presenting information in more appropriate forms and contexts, as an integral part of the CAAD system—and at the right point in the design process—can help to direct attention to possible problems (and delights) for different occupants. In deciding where to allocate the responsibility for affordance detection, we need to consider CAAD systems and their operators (designers) as a whole system. Just as this paper has argued for the need to consider buildings in relation to those who will use them, so the same logic applies to CAAD systems and their users. A major part of our future research is to identify the appropriate division of labour between machine and human.

8. ACKNOWLEDGEMENTS

I am indebted to many people who have helped to shape the ideas presented in this paper. In particular, I would like to thank graduate students in the Department of Architecture, Carnegie Mellon University, Pittsburgh—Jason Brooks, Brian Gardner, Can Gunduz and Smita Gupta—with whom I enjoyed many fruitful discussions about the computability of affordances. I would also like to thank *Graphisoft* for providing the API for *ArchiCAD* free of charge.

9. REFERENCES

Alexander, C., Ishikawa, S. and Silverstein, M., 1977, *A Pattern Language: Towns Buildings Construction*, Oxford University Press, New York.

Altman, I., Lawton, M.P. and Wohlwill, J.F. (eds.), 1984, "Elderly People and the Environment", in: *Human Behavior and Environment: Advances in Theory and Research*, Volume 7, Plenum Press, New York.

Dreyfus, H.L., 1996, "The Current Relevance of Merleau-Ponty's Phenomenology of Embodiment", in: *Electronic Journal of Analytic Philosophy*, University of Indiana, http://www.phil.indiana.edu/ejap/1996.spring/dreyfus.1996.spring.html, pp.8.

Gibson, J.J., 1979, *The Ecological Approach to Visual Perception*, Houghton Mifflin, Boston.

Koffka, B., 2000, "From caves to space stations." Presentation delivered in *The Robert L. Preger Intelligent Workplace*, Department of Architecture, Carnegie Mellon University, Pittsburgh.

Ingold, T., 1992, "Culture and the perception of the environment", in: E. Croll and D. Parkin (eds.), *Bush Base: Forest Farm – Culture, Environment and Development*, Routledge, London, pp.39-56.

Merleau-Ponty, M., 1962, *Phenomenology of Perception*, trans. from the French by Colin Smith, Routledge and Kegan Paul Ltd, London.

Papanek, V., 1985, *Design for the Real World*, Thames and Hudson, London, 2nd edition.

Rowe, P.G., 1987, *Design Thinking*, MIT Press, Cambridge, Massachusetts.

Schwarz, B. and Brent, R. (eds.), 1999, *Aging, Autonomy and Architecture: Advances in Assisted Living*, The John Hopkins University Press, Baltimore.

Tweed, C., 1999, "Prescribing designs", in: A. Brown, M. Knight and P. Berridge (eds.) *Architectural Computing from Turing to 2000: Proceedings of the 17th Conference on Education in Computer Aided Architectural Design in Europe*, eCAADe and The University of Liverpool, Liverpool, pp.51-57.

Tweed, C., 1998, "The social context of CAAD in practice", in: C. Branki and K. Zreik (eds.), *Cyber Design: Proceedings of the Seventh International Conference on Applications/Implications of Computer Networking in Architecture, Construction, Design, Civil Engineering and Urban Planning*, EuropIA Productions, Paris. pp.177-194.

Tweed, C., 1997, "The predominance of the visual in computer-aided architectural design", in: A. Asanowicz, and A. Jakimowicz (eds.) *CAAD - Towards New Design Conventions*, Technical University of Bialystok, Bialystok, Poland, pp.269-285.