VISUALIZATION OF THE IMPACT OF TIME ON INTERNAL FLOORING

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This paper forms part of a broader research into the development of a building maintenance programme through visualization of the building as it degrades over time. In a previous work, by the authors, the overview model of building maintenance visualization has been given in which the behaviour of building components are mathematically analysed before submitted for VRML representation.

In a later effort, the authors addressed, in greater detail, the visualization of the lighting system of a building through time. The work analysed the lighting systems from various perspectives and formulated their probabilistic behaviour, by developing a generic algorithm for the Probability Density Functions (PDF) representing the behaviour of the light source.

In compliance with the objectives of the broader research, this paper focuses on the flooring system of a building with particular reference to carpeting and the manner carpets degrade over time. To this end, a better understanding of the pattern and rate of usage (access) is an imperative. Thus, the concept of anthropy has been adopted to describe the movement behaviour of 'subjects' and to develop an understanding about the pattern and density of carpet usage. This behaviour is then expressed in mathematical forms.

Keywords: building maintenance, carpets, flooring system, visualization, VRML.

INTRODUCTION

The interest in lifecycle costing of a building and the provision of service over the life of a building, has been on the increase. Subsequently, the development of an appropriate and accurate long-term maintenance schedule has gained significant importance. Further, such programmes must be developed well in advance of building occupation, or indeed, building construction. The traditional estimators' approach and reliance on quotations from sub-contractors is subject to grave miscalculations resulting in under-estimation or over-estimation of maintenance costs. Considering the fact that the average life of a building is around 20 years (in comparison to construction time being 1-3 years), these miscalculations can accumulate to what amounts to gross misconduct. In order to yield a degree of accuracy and consistency, proactive construction firms have developed a database of constituent elements of building maintenance from which a better estimate of values are obtained.

As far as facilities management is concerned, the concern goes beyond financial considerations. The provision of a effective and efficient service is a prime concern of many firms venturing for the integration of design, construction and facilities management. An intervention (such as changing the carpets) to soon, is to compromise the cost, whereas, intervention too late is to compromise quality of service.

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In the light of the above, the authors have been involved in a broader research into the development of an alternative approach to the development of building maintenance programme. It has been envisaged that the visual approach will yield a better outcome than traditional approaches. Therefore, a model of visual approach to building maintenance schedule has been suggested (Rad and Khosrowshahi 1997). Basically, the model draws information from the CAD drawing and checks the information against the properties of building components. Then, based on their behaviour, expressed in terms of their PDFs, the state of all items is determined at any given time, before they are visualized through VRML.

There are many building components each with vast variety of options and features. Therefore, it is imperative that visualization is based on generic algorithm(s), whereby, the impact of events and time is defined mathematically and visualized accordingly. The mathematical representation of the lighting system of a building has already been proposed by the authors (Khosrowshahi and Rad 1998).

This paper addresses the internal flooring by focusing on the carpeting system. The simulation of the behaviour of a flooring system is determined by the pattern of movement and the intensity of impact. The latter includes rate of movement, and the quality and type of the flooring system. The work meets the challenge of determining the general definition of the density and pattern of carpet usage in any normal (typical) environment. To this end, Anthropologic description of human movement pattern has been applied and the mathematics associated with this approach has been used to described the behaviour of the pattern of access and usage.

HUMAN MOVEMENT PATTERN

Lang *et al.* (1974), have suggested that one of the objectives of architectural design is to create spatial layouts which will provide for the activity patterns required by a set of building users to achieve their goals. This involves an understanding of movement patterns, human physical dimensions, and the far more subtle uses of space such as for territory and settings for interaction between people. In recent years the work of Sommer (1969), Hall (1966) and others has provided architects with a better understanding of personal space and proxemics.

While activity patterns are relatively easy to establish, it is important to understand the complex system of behavioural components which underpin them.

There are two useful units for analysing human spatial behaviour:

- *Activity system* (Chapin 1968); is primarily concerned with the organization of the sequence of activities taking place in a setting.
- *Behaviour Settings* (Barker 1968); concerned with the relationship between the setting and a recurring pattern of behaviour.

Spatial behaviour is very much affected by the physiology, personality, social group membership, and culture of an individual and the environment in which he operates. Ergonomics, the discipline relating to human physiological process to the performance requirement of work tasks, and anthropometrics, which involves the detailed anatomical measurements of the human being and behavioural capabilities (Morgan 1963, Dreyfuss 1967)

In this paper, the main focus is on the human movement patterns base on the general activity pattern theory. Dreyfuss (1967), and other human factor analysts have

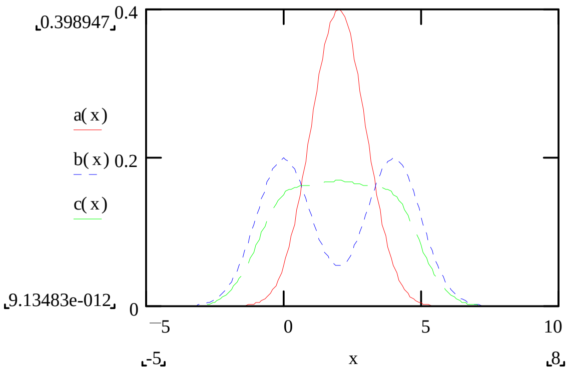

Figure 1: The probability of presentation of one, two and three creatures based on Anthropy

suggested that the human movement patterns are result of anthroposophy. In general term anthropy is knowledge of human kind, and behaviour.

Anthropology, is built based on two basic behaviour of human being:

- Anthroposophy; which deals with human wisdom in his environment.
- Anthropocentric; which deals with human centric tendencies.

Based on this theory, humans tend to acquire more wisdom and place themselves at the centre of their world: on the one hand, humans have the centric tendency to form colonies, on the other hand, they desire to distance themselves from each other. This conflicting behaviour of humans forms the basis of anthropy. According to Tregenza (1976), the number of people who can accommodate within a corridor is a function of the walking speed and the area occupied by each person:

Flow rate = mean speed x mean density x width of route

Also it has been claimed that the density, follows a normal distribution that formed by width of route and mean speed. Based on this concept and in the absence of external biases and interventions, the following mathematical expression (controlled standard normal distribution) is a one dimensional (line) representation of the behavioural pattern of an individual (subject).

$$f(x, y) = \frac{1}{\sqrt{2\pi}} e^{-\frac{(y-x)^2}{2}}$$

Here, x is the random variable and y determines the centrality of the behaviour. The value of y is determined by anthropologic exponentially-based expression. Below, tangible examples are used for demonstration purposes. Graph *a*, in Figure 1, shows the centrality selected at *2* which is almost in the middle of the arbitrary scale from *0* to *5*m where:

$$a(x) := f(x, 2)$$

As the number of subjects increases, the centrality of the combined curves is altered. This is shown by the following expressions representing graphs *b* and *c* for two and three subjects respectively.

$$b(x) := \frac{f(x,0) + f(x,4)}{2}$$

$$c(x) := \frac{f(x,0) + f(x,2) + f(x,4)}{3}$$

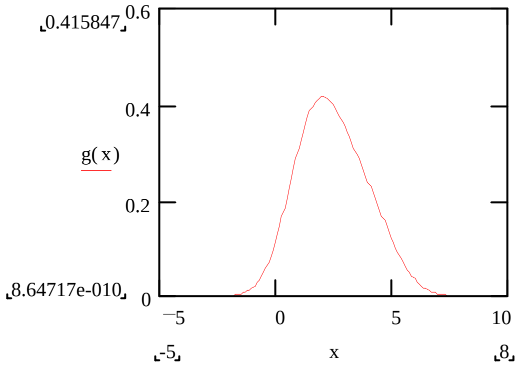

Figure 2: shows g(x) for i=1 and j=5

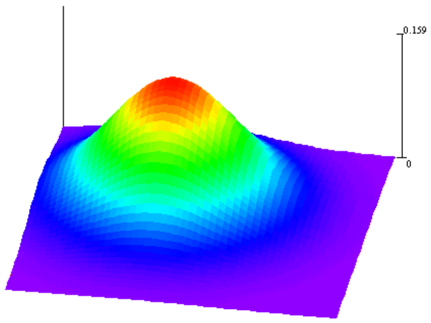

Figure 3: Two dimensional representation of the pattern

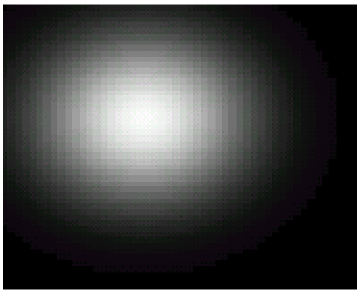

Figure 4: Presentation of the probability of appearance of n creature in two dimensional space

For the model to represent the population or colony of subjects, it should be expanded to represent *n* number of subjects, when *n* approaches infinity. The expression representing the behaviour of a colony is as follows;

$$g(x) = \int_{y=i}^{j} \frac{f(x, y)}{y} dy$$

As demonstrated in Figure 2, the graph representing the behaviour of *n* number of subjects, between i=*1* and j=*5*, will assume a normal distribution curve.

Figures 1 and 2, are one dimensional (line) representation of the pattern of behaviour. A two dimensional (flat) representation is shown in Figure 3. The projection represents the density or probability of appearance.

The plan view of the flat anthropy (Figure 3), is shown in Figure 4, where lighter colours represent the highest probability (density) and darker colours represent the lowest probability.

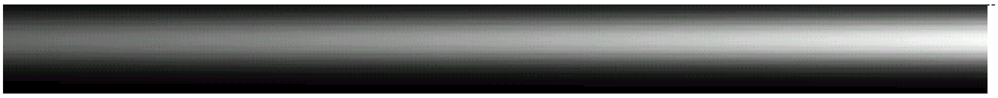

Figure 5: The presentation of probability of appearance of n creatures in a long room (Corridor) with one entry (Door)

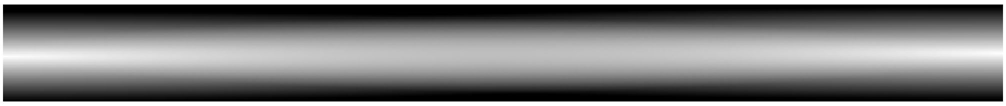

Figure 6: The presentation of appearance of n creatures in a long room (Corridor) with two entries (Doors)

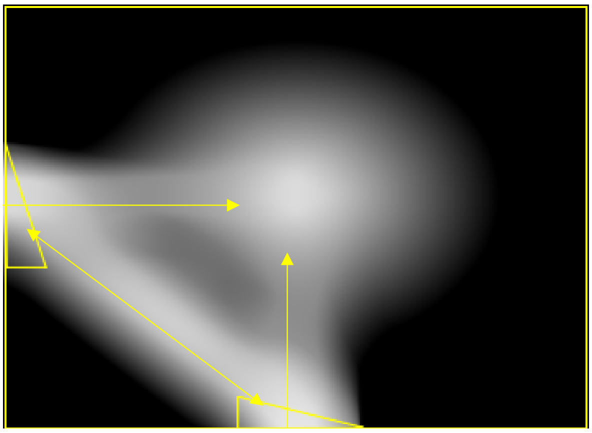

Figure 7: Movement density pattern for a room with two communal doors

The extrapolation of the same principal and its projection over a long two-dimensional length (corridor) will produce a pattern of density (probability of appearance) along the corridor. Figure 5, is the representation along a corridor with one entrance (on the right) and Figure 6, is the same for a corridor with a flow (two identical entrances at each end, both with similar properties).

Figures 5, and 6, represent straightforward corridors with predictable behaviours. However, in real life there are varieties of configurations and room layouts that the environment can assume. For instance, the entrances may not be symmetrically placed. The methodology for the incorporation of all possible configurations and layouts is based on the superimposition of blocks of basic known anthropic models.

Figure 7, is the two dimensional representation of the movement density pattern of an empty room with two communal entrances on two adjacent walls. This pattern is generated by positioning and super-positioning of 3 corridors together with a flat anthropy. The position of the corridors of movement is shown on the figure. While the pattern within each corridor is based on anthropic modelling, the positions of corridors and flat too are based on anthropic behaviour.

It should be noted that the above behaviours apply to non-biased and un-intervened circumstances. For instance, by placing an observatory telescope at the end of the corridor in Figure 5, the pattern of behaviour will change significantly. Also, by introducing an intervention such as placing a round table in the middle of the room, the pattern of movement on and around the obstacle (round table) will be affected. This will in turn increase the complexity of the movement pattern.

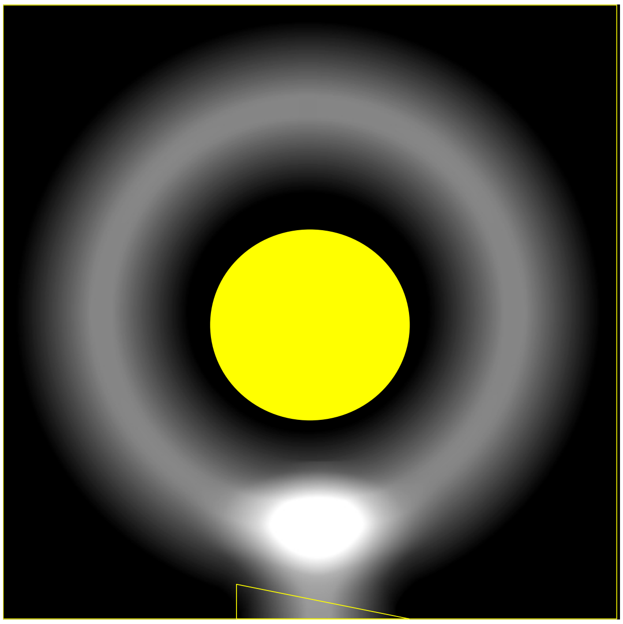

Figure 8: Movement density pattern for a room with one door and circular table on centre

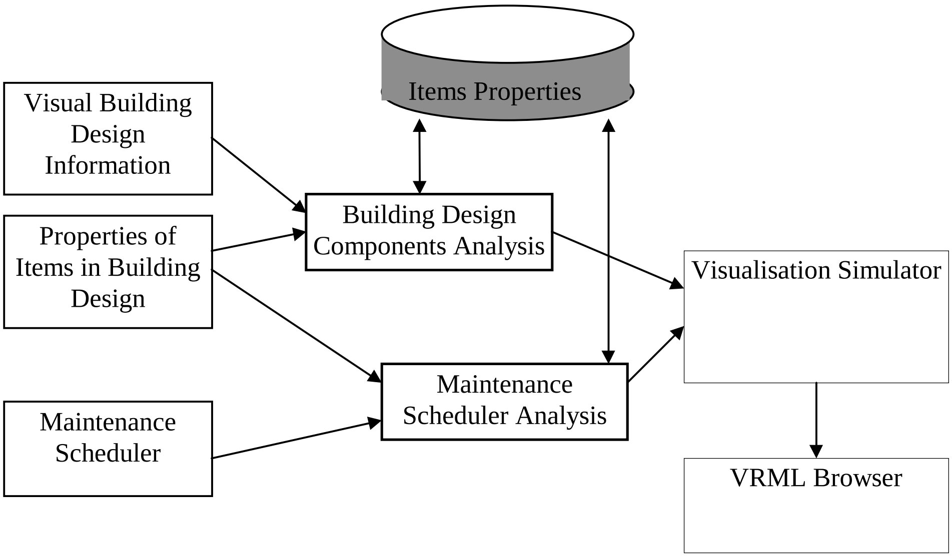

Figure 9: Generalized simulation model

As shown in Figure 8, by placing the round table in the middle of the room with one communal entrance the movement density will assume a different pattern to that of a room without a round table. For start, the space underneath the table is no longer accessible. This implies a zero movement density (zero probability of occurrence) for the occupied area, thus the shaded area.

Further, the space in the vicinity of the table, immediately surrounding it, is also restricted. In effect, the round table has created an anti-anthropy which behaves similar to anthropy (Figures 3 and 4), but in an inverse order. Therefore, the density pattern shown in Figure 8, is generated by super-positioning an anti-anthropy on top of an anthropy.

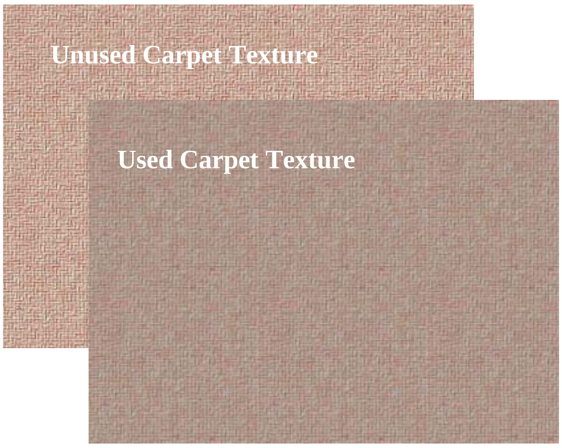

Figure 10: Used and unused carpet texture

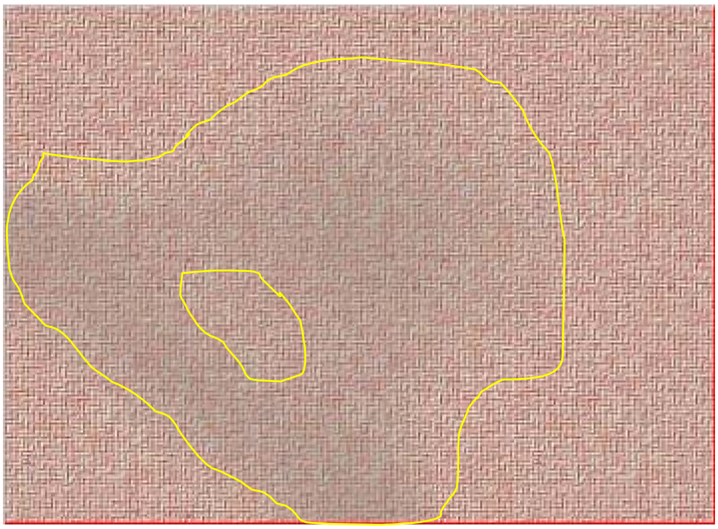
Figure 11: The used carpet texture

VISUALIZATION OF THE DEGRADATION OF FLOORING SYSTEM

The visual simulation of the behaviour of flooring systems ‘through time’ is based on the generalized visualization model of building maintenance schedule (Rad and Khosrowshahi 1997). The model is shown in Figure 9.

Based on this model, the design information from the CAD drawing results in the identification of the items comprising the design. These items are then analysed, acquiring information from the accumulative database containing the properties of items. This information, in conjunction with the maintenance schedule are fed into the visualization simulator which facilitates a VRML output. This process is time-dependent, thus a different output is generated at different points in time.

Having determined the density pattern of movement and usage, we can now ascertain the impact of time on the flooring system of a building. The time-related influencing factors include rate of usage, the fabric of the floor, the environment, the period of usage, etc. These factors determine the intensity of the impact of time on the flooring system. Basically, this information is obtained through a data collection exercise (from manufacturers for flooring specifications and through observation for the rate of

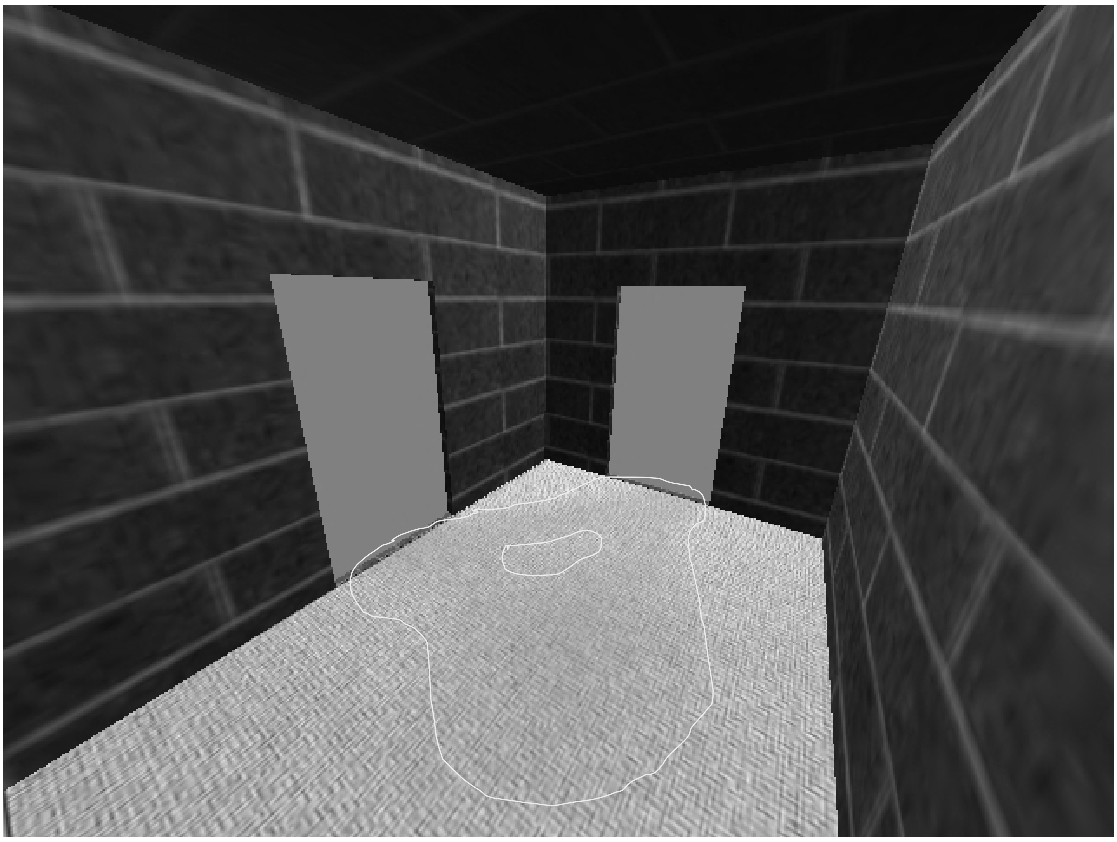

Figure 12: A room with two doors after two years

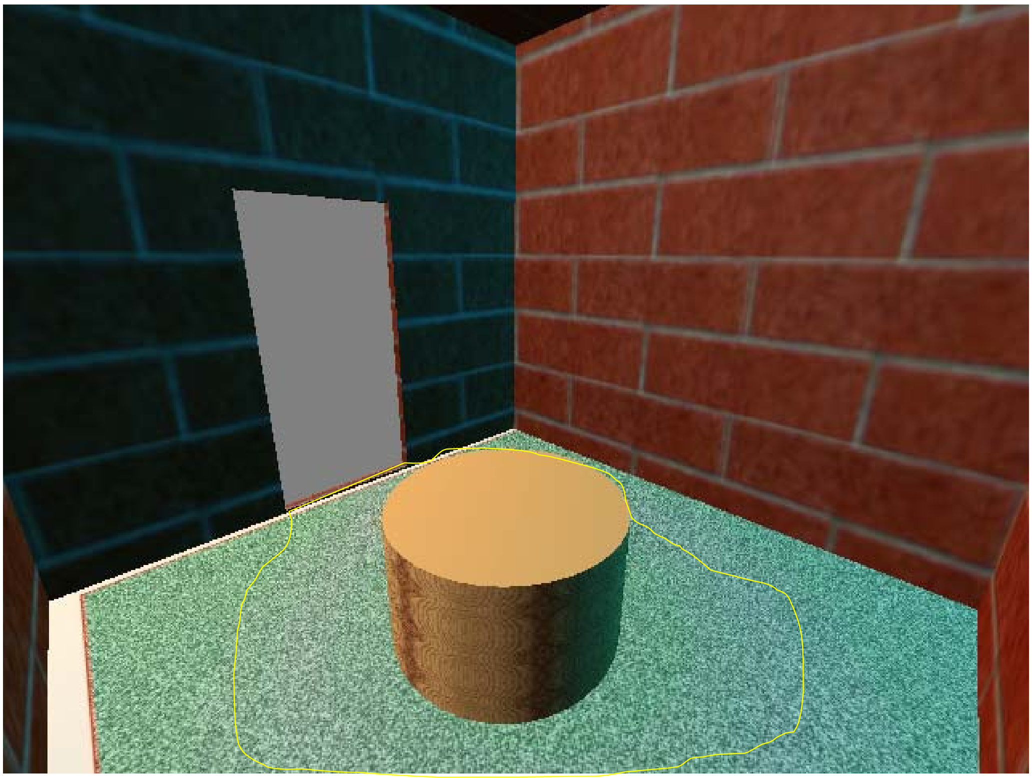

Figure 13: A room with circular table in centre after 18 months of use

usage). An accumulative database of relevant information should be generated containing indexed data relating to a variety of situations. The data is then applied, as a coefficient, to the density pattern of movement. However, the focus of this paper is on the movement pattern (as described earlier) and the method of simulation of usage through VRML.

VISUAL REPRESENTATION THROUGH VRML

The use of textures and texture mappings is an straightforward task within VRML. However, since the movement density is a localized phenomenon (only affecting certain areas, based on anthropy), the simulation of localized degradation is not directly possible through VRML. Therefore, a Visual Basic programme has been written to generate the status of the degraded carpet. This is carried out through the application of weighted texture mapping from the combination of unused and used states, based on the movement density pattern. Accordingly, the colour attributes of unused and used carpets textures are aggregated on the basis of weightings produced by the density pattern.

In Figure 10, a complete unused carpet is contrasted against a complete used same type of carpet. The aforementioned Visual Basic programme has been used to calculated and map the textures, using weighted textures produced by the movement density pattern in Figure 6. The result is shown in Figure 11, highlighting the affected area.

The use of VRML for simulation of flooring degradation is demonstrated in Figure 12: the carpets is uniformly applied to the whole room, with two entrances, and the used area is highlighted. The same is shown in Figure 13, however, this time a round table is placed in the middle of the room. And there is only one entrance.

CONCLUSION

The paper reiterated the importance of an effective building maintenance programme in life cycle costing, life cycle services and facilities management provisions. To this end, the effectiveness of the visualization of the building through time, as it ages, was highlighted.

The paper made a significant contribution to the broader research programme into the visualization of the degradation of a building, by addressing the issues relating to degradation of flooring system of a building with the passage of time and usage. A major achievement of the paper was to proposes a universal method for determining the density movement of people defining the pattern of usage. This has been based on the principal of anthropy: systems such as humans tend to engage in a conflicting exercise of tending to position themselves in the centre of their environment and yet maintaining furthest distance from one another. Initially, anthropy was applied to straightforward situations. This exercise provided the basic building blocks for extending the concept to more complex carpet configurations and room layouts. This was achieved by superimposing individual anthropy models resulting in the development of the movement density pattern.

Also, the impact of the introduction of an obstacle such as a table was addressed through the application of anti-anthropy to the area immediately surrounding the obstacle. Next, the paper proposed a method for mathematical representation of the degradation through weighted mapping of the movement density pattern and the unused flooring texture. Finally, the paper demonstrated the visualization of the degradation through the use of VRML.

REFERENCES

Barker, Roger G. (1968) Ecological psychology: concepts and methods for studying the environment of human behaviour. Stanford, CA.: Stanford University Press.

Chapin, F. Stuart, Jr. (1968) Activity systems and urban structure; a working schema. *Journal of the American Institute of Planners*, **34**: 34.

Dreyfuss, H. (1967) *The measure of man: human factors in design*. 2ed. New York: Whitney Library of Design.

Hall, E.T. (1962) *The maddening crowd: space and its organization as a factor in mental health*. *Landscape*. **12**: 26–30.

Hall, E.T. (1966) *The hidden dimension.* Garden City, N.Y.: Doubleday.

Lang, J. *et al.* (1974) *Designing for human behaviour*. Dowden, Hutchinson & Ross.

Morgan, Clifford T., *et al.* (1963) *Human engineering: guide to equipment design.* New York: McGraw-Hill.

Rad, H.N. and Khosrowshahi, F. (1997) Visualization of building maintenance through time. *In: Procs International Conference on Information Visualization* IV’97, 27-29 Aug., London, England, 1997.

Sommer, Robert (1969) *Personal Space: the behavioural basis of design*. Englewood Cliffs, N.J.: Prentice-Hall.

Traegenza, P. (1976) *The design of interior circulation*. London: Granada.

VRML 2.0 Final Specification, “http:// www.vrml.org/ VRML2.0/FINAL” International Standard ISO/IEC 14772-1:1997, The VRML Consortium Incorporation, 1997.