Assessment of Building Performance Using Computational Intelligence: Focus on the Disabled and Elderly

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The care for the elderly and people with disability increasingly demand more ingenuity to undertake, especially as it relates to the built environment. The impact of the physical environment on health has been widely documented. The knowledge of the special needs/preferences of this vulnerable group of users (people suffering from Alzheimer, autism, dementia and other similar disabilities), for the purpose building of performance evaluation and subsequent improvements is essential. The challenge is that their conditions, as exemplified by the loss or impairment of their capacity to provide accurate/realistic information of their building attributes' perceptions and preferences, make such knowledge inaccurate to serve as basis for building improvements and designs. This paper seeks to provide a scientific means for obtaining more accurate knowledge, which when obtained normally can be misleading and non representational of reality. The method adopted for this study is fuzzy-neural-network computation, a branch of computational intelligence, to develop an all-encompassing knowledge based building performance assessment model.

Keywords: *Building-performance-assessment, Elderly, Fuzzy-neural-network*

INTRODUCTION

The environment accounts for the wellbeing of human, in terms as part of social, cultural and health measures. The built environment being largely what defines the environment (building and surrounding) is at the core of this wide term 'environment'. It has lately become more apparent that the relationship between health and building is more far reaching than commonly perceived, as illustrated by sick 'building syndrome', the user can be sick especially in public and institutional buildings as a result of the impact of building on him or her. This effect is more apparent with elderly and disabled, who are either permanently or temporarily suffering from health impairment as a result of ageing or disability, while the buildings do not take their impairment into account sufficiently.(Solar & Irwin, 2007)

Aim

The aim of this research is to reach optimal building performance, for enhancing health comfort of elderly and disabled people. An essential step towards realizing this aim is developing a model for the precision assessment of buildings' performance

from the standpoint of the group.From the scientific viewpoint the work addresses the issue of how to bring into computational form the complex information on the performance of a building from standpoint of elderly and disabled. In particular the issue of coping with the soft nature of the knowledge being modeled is tackled. It demonstrates the suitability of neural computation for this purpose.The introduced model will offer a factual platform for measuring the performance of buildings for this user group leading to better understanding of their needs, especially by the following stakeholders:

- Building designers and post occupation evaluators
- Care givers
- Building facilities managers

The adopted method, with the feature of adaptability to most situations gives better and more realistic representation of the satisfaction needs of the elderly and the disabled who are at cross road as to how there special needs can be understood and taken care of as they battle with the challenges of their condition(s). Situations associated with ageing and disability. This instability is what this method will address adequately, thereby making it unique for both pre and post occupation evaluation tailored to the needs of elderly and disabled.

Designers of buildings that are be used by elderly and disabled will benefit from this, as they will by this also have a means of understanding what they need to adjust or upgrade in the building environment to help bolster the satisfaction of their target group.

LITERATURE

Research Theory and Context

The following statements, as contained in studies of architecture, environment, gerontology and disability research aptly captures the context of this research:

"There is a risk that disabled persons develop a negative self-image as a victim of the disability. A manageable environment could contribute to the mediation of a negative self-image. It can be claimed that the social model of disabilities has detached the bodily experience from the physical environment. For good reasons, for instance to get away from the medicalization of infirmity, this model declares that disability is a social construction. The social model of disability has its physical counterpart in the "inclusive design" paradigm. The latter is of course by its physical nature closer to the body and its experiences. "Since there has been life on earth it is our feet which remind us we are alive. We know we exist when we feel it in the soles of our feet and all of us in infancy begin by learning to walk" (Ando quoted in Frampton 2002:318)." (Gursel, I., et al., 2009)

It is for these reasons that attempts are continually made to enquire about users' satisfaction through performance assessment. Post occupation evaluation (POE) is a common means for this in the built environment. The results of the assessment help in keeping in tandem with changes by serving as basis for solution(s).

The task of dealing with the interest of elderly and disabled people is particularly difficult due to the different type of physical or mental challenges, leading to expectedly large variance among the people's perception. It is this extra over challenges that this research is focused at proffering solution(s).

The features of neural computation that are desirably needed for this class of study are that:

- It is able to deal with the complexity of environmental information, which is characterised by many attribute relations and non-linearity among the relations.
- It is robust and fault tolerant.
- It is flexible. It can adjust to a new environment by "learning"
- It can deal with information that is fuzzy, probabilistic, noisy or inconsistent.

The ability of the method to deal with the complexity of the environmental information provided by the

elderly and disabled is the motivation for its adoption for this method for this research.(Hertz, Krogh, & Palmer, 1991)

A neural tree structure is considered with nodes of neuronal type that is a Gaussian function and it plays the role of membership function. The total tree structure effectively works as a fuzzy logic system having system inputs and outputs. In this system the locations of the Gaussian membership functions of non-terminal nodes are unity so that the system has several desirable features and it represents a fuzzy model maintaining the transparency and effectiveness while dealing with complexity. The model has transparent fuzzy modelling properties and addresses complexity issues at the same time.(Ciftcioglu, Sariyildiz, & Bittermann, 2007)

Health and the Built Environment

Goldsmith, (1997) posited that the disabled is an ambiguous term. It can mean, as it usually does, people with disabilities, those who got something wrong with them, which a physician can describe. That is the medical model. Or it can mean people whether or not they be 'medically' disabled, who are in some other way disabled - who are financially disabled, for example, or socially disabled, or 'architecturally disabled'. It is architecturally disabled people with whom this research is concerned. Those who when using or attempting to use buildings can find themselves confronted by impediments which prevent them from doing so or allow them to do so only with difficulty and inconvenience.

The research is but concerned with measuring the perceptions of features of a building as to understand their effects on satisfaction of elderly and disabled, providing basis for optimal solution(s).

The groupings of impairments are:

- Physical or mobility problems
- Sensory loss
- Long term health problems
- Co-ordination and intellectual impairment
- Psychiatric or emotional/motor co-ordination.

These characteristics translate to emotion and mood swing. This is one of the features that mark the group out as different from others. The ground for the special attention is thus hinged on their vulnerability caused by their mental state.

Attention is usually paid to the need to investigate how central and the extent to which the following factors serve as basis for measuring and also their impact on elderly and disabled persons' health:

- Outdoor environment
- Indoor environment
- Security
- Safety
- Landscape - Garden
- Parking lot
- Private rooms
- Common rooms
- General facilities

Building performance assessment

Much research has been done in performance assessment. There have been so many propositions, some based on geographical location, government etc. that it appears not much is left to do. However in general the performance concerns crisp, engineering variables such as energy, stress, and son on, while soft aspects such as appreciation of a building have been ignored largely. This is presumably also due to the complexity of soft aspects. There has been an imbalance in the focus of the assessment; there exists a gap in the focus, the neglect of perception and assessment of spatial quality, in particular from the standpoint of the elderly and disabled people about the built environment. (Lutzkendorf, T., and Lorenz, D.P., 2006).

Choice Option	Very Dissatisfied	Dissatisfied	In between (Indifference)	Not Dissatisfied	Not at all Dissatisfied
Rated Value	0.1	0.3	0.5	0.7	0.9

Table 1
Questionnaires response rating values.

Gursel, I., et al (2009) explained that building performance assessment refers to the identification and quantification of the performative objectives that a building is expected to satisfy, and the utilization of means for the evaluation of the building in order to assess its lifecycle performance quality. The aim of this approach is to enable the design and execution of buildings that are highly suitable for their occupants, considering thermal, acoustical, visual, environmental, safety-, comfort, and health-related aspects.

METHOD & APPROACH

The research method adopted for this study is 'mixed' - in that it combines both qualitative and quantitative aspects. Expert knowledge, with statements from users, that are qualitative in nature is obtained and analySed quantitatively using neural computation, effectively establishing a model. For this, information is obtained through observations, interviews, and questionnaires. Advanced computational method of neural computation will be used for both analysis and model development. The use of neural computational method to gain factual information from the complex mindset of the group is the hallmark of this research. The information is characteriSed by 'volatility of mood and emotion' making understanding them so daunting that the simple statistical methods are inadequate.

The core method adopted for this study is fuzzy neural network in the domain of computational intelligence. The information used in the network analysis was obtained using qualitative methods of interviews, observations and questionnaires. It is safe to say that dual methods are used for this research. The main tool used being fuzzy neural network (neural computation).

The choice of this method is premised on its novel strength of dealing with fuzzy information that is conventionally considered not to be amenable for easy computation.

The survey/data collection for this study were obtained through the following means:

1. Observations
2. Open-ended Interviews
3. Structured questionnaires

Visit and interactions with people in buildings frequently used by elderly and disabled people offered the needed opportunity to gain comprehensive insight through.

Interview with the following experts and health care personnel helped to verify the structure of the model. Some other experts interviewed are: Geriatricians, Physicians, Nurses, Care home managers, Facilities managers, home care givers, and Designers.

The questionnaires (a part of which is shown in Table 1) have five options with value ratings as indicated in Table 2.

For these purpose fifteen experts were interviewed asking structured questions aimed at confirming or disputing some of the observations/perceptions.

The respondents to the main questionnaires (Table 1) are the elderly and the disabled who were to be randomly sampled for this study. A sample population of 1000 people, grouped into 600 for the disabled and 400 for elderly. The survey was carried out in Nigeria. The spread of the sample population took cognisance of the different types of buildings. (Institutional and public buildings)

Table 2
Part of the questionnaires. (Input questions corresponding to Node 2 of the model Tree).

Indicate how dissatisfied you are with the following Factors/properties of building:
(Mark √ as appropriate)

S/No.	NT ID No.	QUESTIONS A	Very dissatisfied	dissatisfied	In between	Not dissatisfied	Not at all dissatisfied
	1	**OUTDOOR ENVIRONMENT:**					
1	111	Regarding the security of the outdoor environment of your institution, how much dissatisfied are you with the lighting conditions provided (considering if there is enough light you feel secure)?	☐	☐	☐	☐	☐
2	112	Regarding the security of the outdoor environment of your institution, how much dissatisfied are you with the presence of security personnel (considering if there are personnel you feel secure)?	☐	☐	☐	☐	☐
3	113	Regarding the security of the outdoor environment of your institution, how much dissatisfied are you with the presence of security monitoring devices (considering if there are enough monitors etc. you feel secure)?	☐	☐	☐	☐	☐

$$f(X) = w\phi(\|X - c\|^2) \quad (1)$$

$$O_j = exp(-\frac{1}{2}\sum_{i}^{1}\left[\frac{(w_i - 1)}{\sigma_j / w_{ij}}\right] \quad (2)$$

Equation 1 represents the cumulative end point value, these are obtained from the nodal transfers using the transfer functions at each nodes.

The transfer function O_j (equation 2) is applied at each nodes sequentially.

Where j is the layer number; i denote the i-th input to the node; w_i is the degree of membership at the output of the terminal node; w_{ij} is the weight associated with the i-th terminal node and the non-terminal node j. The width of the basis function σ is used to measure the uncertainty associated with the node inputs designated as external input X. The output of i-th terminal node w_i is related to X by the relation , where w_{ij} is the weight connecting terminal node i to terminal node j. It connects the output of a basis function to a node in the form of an external input. The centres of the radial basis functions are the same as the input weights of that node, w_{ij}. (Ciftcioglu, Bittermann, et al., 2007)

The rated values obtained from the questionnaires, were clustered and then used as weights w_i in data analysis and computation.The algorithm used in the computation takes the form of figures 1-4.

RESULT AND DISCUSSION

Table 3 shows part of the computation in excels worksheet. All the variables are combined relationally and hierarchically using the fuzzy neural network computation algorithm. The fuzziness in the variable input data become stabilised and from the computation the outcome for a typical building type - a psychiatric hospital is presented in a final report sheet, in certification format.

The features of the certification report are that:

1. The overall level of perception, in terms of rating is indicated
2. The perception levels for each of the major attributes are also shown on the right hand side of the certification/assessment report - (figure 5)

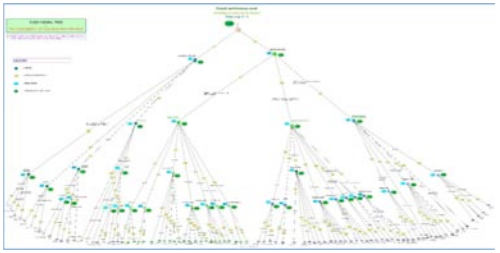

Figure 1
Performance Assessment Neural Tree Model (Figure 1 – Neural Tree structure)

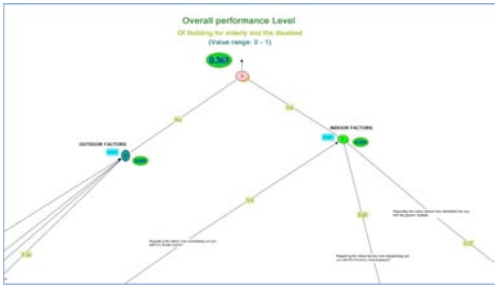

Figure 2
Fuzzy Neural Tree (Performance assessment model) – Close-up 1

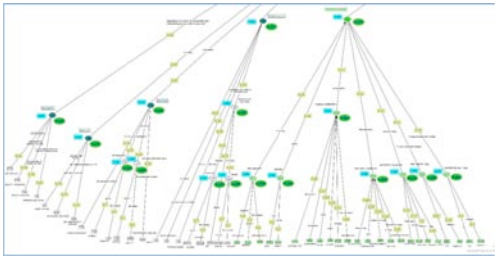

Figure 3
Fuzzy Neural Tree (Performance assessment model) – Close-up 2

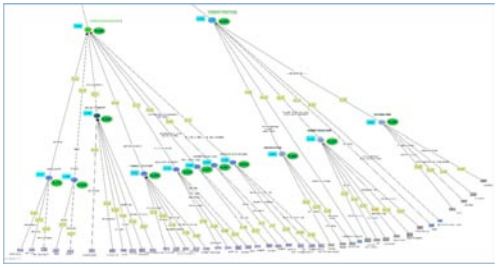

Figure 4
Fuzzy Neural Tree (Performance assessment model) – Close-up 3

Table 3
Data Mining/Computation (part of the excel worksheet)

	RBF - Transfer Fns	In Fn Summation	Transfer Fn i	i = 2
0.4	SUM TOTAL	=SUM(D3:M3)	Wi * μ_i	Wi * μ_i
			1	2
	0.5	0.4656398213	0.0854050348	0.3802347865
PERFORMANCE_0	0.3	0.2902994883	0.0854050348	0.2048944535
	0.3	0.3046958599	0.1032375132	0.2014583467
	0.2	0.2117959600	0.1032375132	0.1085584468
	0.9	0.8772875352	0.3723624511	0.5049250842
	0.7	0.7187857358	0.3404407421	0.3783449937
	0.3	0.2538871960	0.0605223645	0.1933648314
	0.1	0.1435607923	0.0605223645	0.0830384278
	0.3	0.3356621044	0.0942766617	0.2413854427
	0.3	0.3356621044	0.0942766617	0.2413854427
	0.4	0.4450934833	0.1968451289	0.2482483543
	0.4	0.3887881295	0.1405397752	0.2482483543
	0.4	0.3953950780	0.1668286643	0.2285664137
	0.4	0.3903555786	0.1668286643	0.2235269143
	0.4	0.4272267867	0.1181482479	0.3090785388
	0.4	0.4089591484	0.0998806096	0.3090785388
	0.3	0.2991993737	0.1394476986	0.1597516750
	0.3	0.2991993737	0.1394476986	0.1597516750
	0.3	0.2916845548	0.1245718079	0.1671127468
	0.3	0.2856741046	0.1245718079	0.1611022966
	0.3	0.3154697354	0.1281992461	0.1872704893
	0.3	0.3154697354	0.1281992461	0.1872704893
	0.8	0.8142847672	0.3535915129	0.4606932542
	0.6	0.6419331060	0.3535915129	0.2883415931
	0.2	0.2438617502	0.0758031179	0.1680586323
	0.2	0.2438617502	0.0758031179	0.1680586323
	0.2	0.1963817029	0.0805733024	0.1158084004
	0.2	0.1963817029	0.0805733024	0.1158084004
	0.8	0.7544603621	0.3032608233	0.4511995388
	0.7	0.7203909440	0.3032608233	0.4171301207
	0.3	0.3360153025	0.0821028460	0.2539124565
	0.3	0.3115339655	0.0787924296	0.2327415359
	0.6	0.6495002247	0.2045971428	0.4449030819
	0.5	0.4618394261	0.1845574444	0.2772819816
	0.8	0.7567050068	0.2964604806	0.4602445262
	0.5	0.5320766020	0.2840678610	0.2480087411
	0.7	0.6698427227	0.3397315945	0.3301111282
	0.6	0.6485653447	0.3397315945	0.3088337502
	0.2	0.2386644668	0.1040090944	0.1346553725
	0.2	0.2268765598	0.1040090944	0.1228674654

Suffice it to say that with this certification report format. The following decisions can be drawn very easily:

- The building and its surrounding can be judged as being satisfactory or otherwise
- The contributing attributes to this satisfaction level are clearly seen in terms of their contributions to the final perception level.
- The attributes that are of utmost priority to the target users become very clear and intervention can be directed at them base on priority level.

The foregoing summation is preceded by data mining processes and then used in the neural network analysis towards developing assessment model as explained below:

The research survey data was checked for integrity, consistency and generally transformed making them usable for computation. Fuzzy logic principle, a method within the computational intelligence domain was used to develop algorithm for data processing/learning to establish performance output and user preferences.

Specifically parametric values were determined from the data and used in the algorithm. The structure of the algorithm takes after the Fuzzy Neural Tree, Fig. 2. The survey data were first transformed and prepared in matrix forms; computations were carried out with the aid of Microsoft Excel/VBA. The neural tree input layer, consists of 88 input variables, with about 1607 input range, the nodal sigma values were determined based on the established algorithm. The connecting weight values that represent professional knowledge serve as one of the variables in the transfer functions used for node-to-node value transfer until the final output node, where the value obtained represents the overall performance of the building assessed.

Figure 5
Building Performance Model Certification Report (Sample)

CONCLUSIONS

It is concluded that the research outcome can be used to determine how satisfied the users are with the building, the preferences indicated by the scores can equally be used to upgrade areas of the building with poor performance perception as represented by low score in a value range of 0 - 1scale value.

It is important to note the following:

The current methods/means of obtaining knowledge from building users, questionnaires, interview and interactions require further research in collusion with those working of human emotion research to see how emotion sensors can be used to acquire information from the study group. The results so obtained shall be interpreted with utmost care as to separate factors contributing to moods and general

feelings that relate to buildings/surrounding environment from other social factors that might be unrelated to the physical environment.

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