A KNOWLEDGE BASED CAAD SYSTEM FOR DETERMINING THERMAL COMFORT DESIGN STRATEGIES

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ABSTRACT

A computer-aided design system for determining thermal comfort design strategies is presented. The system is based on a knowledge base which stores the existing information concerning thermal comfort rules of thumb, and precise procedural calculations which facilitates the defining of thermal comfort design strategies that best suite the local climatic conditions and the specific constrains of the design problem at hand.

KEYWORDS

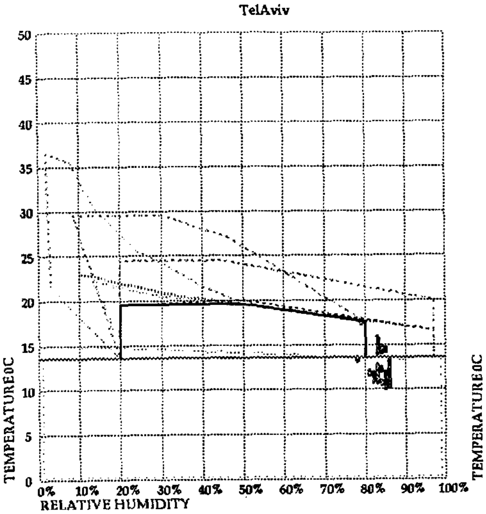
Design tool, CAD, thermal comfort, design strategies, solar and low energy architecture, pre-conceptual design stage.

INTRODUCTION

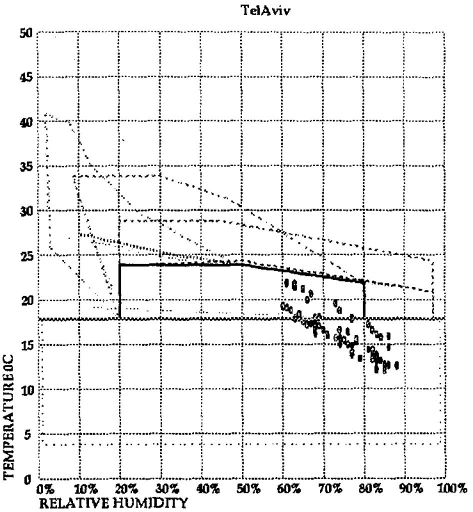
Most Computer-Aided design systems are aimed to serve as an evaluative tool at the advanced design stages, after a design solution has already been established by the architect. However, there are few CAD tools to help the designer in selecting the best suited design strategies at the very early design stages like the pre-conceptual one. The decision about the preferred design strategies also determines the form of the solution and its performance.

Bio-climatic comfort charts have been proposed by different researchers as a method to analyze the local climatic conditions at a given place (ASHRAE, 1989; Olgyay, 1963; Milne and Givoni, 1979; Arens et al., 1980). These charts help the designers to find whether the local climatic conditions fall in the range of what is defined as the thermal comfort zone and to figure what passive and low energy design strategies best suite these conditions. We know however, that the thermal comfort depends heavily on the type of clothing (CLO) and level of activity (MET) and therefore, adaptation of the thermal comfort zone and the different passive design strategies zones on these charts should be corrected accordingly. Such a correction is not an easy task, especially if the whole range should be corrected in order to see the complete picture. Additionally, the designer who is not an expert in bio-climatic design, does not always know the kind of constraints he should select for his current problem. Furthermore, such charts include enormous number of possibilities, and there is no guarantee that the desired climatic design strategy will be selected.

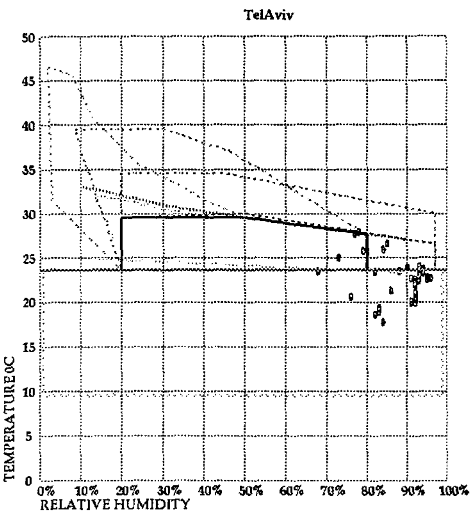
In this work we present a new computer-aided design system for determining thermal comfort design strategies that overcomes the difficulties presented above. This system presents the user with a dynamic and sensitive chart that fits itself to the level of activity, the type of clothing (see Fig. 1) and defines the suitable constraints for the specific type of building. These adaptations can be performed automatically, according to the kind of problem at hand, or as requested by the designer. The system is based on a knowledge base, which stores the existing information concerning thermal comfort rules of thumb, and precise procedural calculations which enable defining very easily the thermal comfort design strategies that best suite the local climatic conditions and the specific constrains of the design problem. The system is aimed to be used already at the very early design stage, i.e. the pre-conceptual design stage.



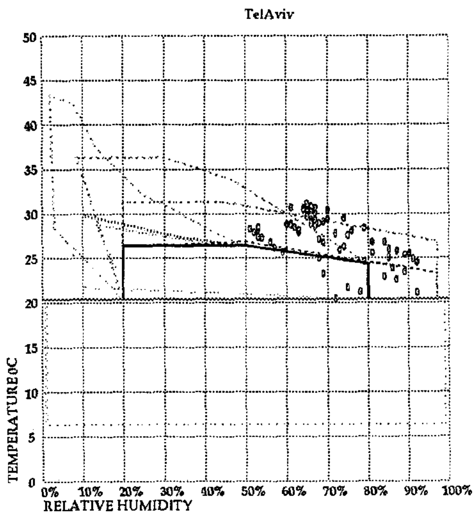
(a) Winter-Night: 3.0 clo 0.8 met



(b) Winter-Day: 1.0 clo 1.6 met



(c) Summer-Night: 0.5 clo 0.8 met



(d) Summer-Day: 0.5 clo 1.6 met

Fig. 2. Dynamic bio-climatic chart for residential buildings.

THE PRE-CONCEPTUAL DESIGN STAGE

In the pre-conceptual design stage first adaptations between project demands as is dictated by the program, specific constraints, specific conditions of the place and the available design strategies are taken place. In this stage local climatic conditions are verified and checked against goals (Shaviv and Kalay, 1990), in order to establish design principles that best suit both place and project.

From the climatic point of view the main goals for this stage are:

(I). To achieve a thermal comfort solution that will require minimal use of non-renewable energy. In other words, to look for energy conscious design solution on one hand, and to use, as far as possible, passive solar and low energy cooling strategies on the other hand so that thermal comfort conditions are achieved.

(II). To reach goal (I) by using minimum thermal comfort design strategies, which means that a smaller diversity passive systems for heating and cooling will be required in the building. Goal (II) will ensure that less different building elements should be added to the building in order to achieve the required thermal comfort, thus obtaining a simpler and more economical solution.

THE KNOWLEDGE BASE REQUIRED FOR THE PRE-CONCEPTUAL DESIGN STAGE

The pre-conceptual design stage is based on a wide knowledge that can be divided into three parts according to place, building type and technology. (Each design stage has these three types of knowledge base, but the context of the knowledge required in each stage is not the same).

The system that we propose is based on both a knowledge base and procedural methods that guarantee the climatic design strategies will fit the local conditions and the type of building. The knowledge base fixes the appropriate level of activity and type of clothing during day and night, for winter and summer (see Fig. 1) and fixes the appropriate range of values for the different constraints. For instance, if the chosen activity is 'residential', than the system will allow higher wind speed in the room (see Fig. 2, where the allowed wind speed in summer is 4 m/s) than if the chosen activity would have been 'offices' (see Fig. 3, where the allowed wind speed in summer is only 1 m/s, in order to avoid that papers flying in the wind). Also, it will assign different values for clothing (CLO) and activities (MET), both for day/night and winter/summer As for example in residential buildings this values for winter will be 1 CLO for day time and 3.0 CLO for the night, and 1.6 MET for the day and 0.8 MET for night time (see Fig. 2), while in the office building it will consider these values only for day time and these values are 1 CLO, and 1.4 MET (see Fig. 3). Moreover, the knowledge base recommends an appropriate comfort zone. For residential buildings a wider zone is applied (see Fig. 2) based on the chart suggested by Milne and Givoni (1979), while for an office building a narrower one is proposed (see Fig. 3) based on the chart suggested by Arens et al. (1980). In this way an inexperienced designer has to deal with only few variables, while ensuring the consistency of the solution. All this is achieved just by clicking 'ADVICE ON' on the vertical menu (see Figures. 2 and 3). On the other hand the expert designer can choose 'ADVICE OFF' and examine any design variable by assigning different values to it. Thus he can "feel" the influence of the different design parameters on the space of possible solutions. For example, he can learn that just by dressing more heavily in winter or less in summer, thermal comfort may be achieve without adding mechanical means.

CREATING SOLUTIONS FOR DETERMINING PASSIVE COOLING AND HEATING DESIGN STRATEGIES

Since our design tool is a computerized one, it can carry out an hourly analysis of the climatic conditions in any specific location during the whole year. This is done after all the constraints are set up, either by the expert system, or by the designer. The analysis is performed with respect to these constraints. The examination of the data consists of calculating the percentage of time during a month, a season, and the whole year, that the point presenting the hourly climatic condition (temperature and humidity) falls inside the borders of the thermal comfort zone, or any thermal comfort design strategy. In such a case it is added to the total number of times such an event occurred.

Simple Solutions

First "simple" solutions are proposed instantly by the system (see right side of Fig. 2). These simple solutions are composed of only one cooling strategy and one heating strategy. The evaluation of each simple solution is performed and presented graphically and numerically for each month, season and for the whole year.

Each simple solution is represented by four parts as follows:

a. The first part indicates the comfort zone (CZ) i.e. it shows the percentage of time that the points presenting the climatic conditions (temperature and humidity) fall inside the boundaries of the comfort zone.

b. The second part is the passive solar heating strategy (PSH) i.e. the percentage of time that there is a need to provide heating in order to achieve comfort conditions. There is only one heating strategy defined in all the thermal comfort charts, and it represents in general the requirement for any passive solar system.

c. The third part represents one of the four possible cooling strategies i.e. the percentage of time that there is a need to provide a passive cooling strategy in order to achieve comfort conditions. The possible cooling strategies are natural ventilation (NV), artificial ventilation (AV) using basically fans and ventilators, high thermal mass with night ventilation (HTM), and evaporative cooling (EC).

d. The fourth part is the amount of time that we need to provide the building with a non-renewable energy in order to achieve thermal comfort conditions. The need for non-renewable energy occurrs when the sum of the above three parts is not 100%, otherwise its value is zero.

The overall evaluation for the simple solutions takes on the SGI Indy workstation less than a second. This means that the evaluation of any change that the designer makes on any constraint value, or on any design parameter, are presented simultaneously on the screen and can be appreciated by the designer. If the designer is not satisfied with the results of the simple solutions he may ask the system to generate and present him different "composed" solutions.

Composed Solutions

Contrary to the simple solutions that consist of only one passive cooling design strategy, the composed solutions consist of more than one. (See the top part of Fig. 3). Let us mention that the bio-climatic chart includes only one zone that presents passive heating design strategy (without describing the kind of passive solar system preferred). However, it shows more than one possibility for selecting a passive cooling design strategy. Moreover, the designer has the freedom to select more than one passive cooling strategy at the same time. This means that there exist different combinations to achieve a complex solution. When the designer selects 'ADVICE ON', the system takes care that any solution that includes more cooling design strategy than the former created solutions, should be better, in terms of thermal comfort and minimal use of non-renewable energy, than the previous created solutions. Such an evaluation which is performed automatically while creating new solutions, guarantees that the two main goals presented before are satisfied (i..e. using as much as possible passive solar energy and achieving a low energy solution by using less different building elements). On the other hand the designer can choose 'ADVICE OFF' in order to create and examine any possible design solution he wishes to test.

The overall evaluation of two strategies takes less than a second on an SGI Indy workstation. Evaluation of three strategies takes less than five seconds, and of four strategies about 15 seconds only. In any case the designer may choose the number of combinations he wants.

The next design stage will be to examine the different available passive solar systems in order to choose the one that best fits the local conditions and the type of building in a way that both goals presented before will be satisfied. In order to maintain the flow of the process, the composed solutions presented on the top part of the screen (see Fig. 3) turn to be an active menu where the designer may choose any of these solutions as the preferred one. However, the description of choosing the best passive heating system, which is not embedded directly in the bio-climatic chart, is out of the scope of this paper and will be presented elsewhere.

SUMMARY AND CONCLUSIONS

In this work a sensitive bio-climatic chart is suggested as a CAD tool for determining all possible combinations of passive cooling and heating design strategies. This design tool is aimed to be used in the early pre-conceptual design stage. The CAD tool suggested here is based on integration of a knowledge base and procedural methods to allow achieving solutions that best fit the local climatic conditions and the type of building. The knowledge base defines the correct conditions and constraints that fit the problem at hand, so that a non bio-climatic expert user of the system does not need to worry about the correct values he should assign to the many different existing variables of his current problem. The system lets the designer to easily learn about the influence of the different climatic and design parameters on the best design strategies that he should select, thereby a good solar and low energy building will be both designed and achieved.

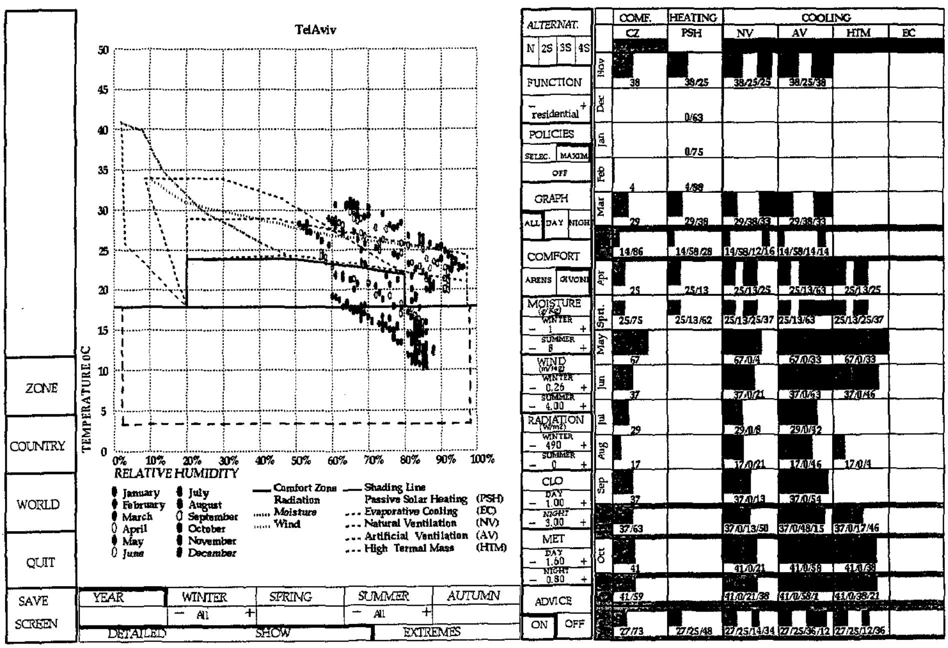


Fig. 2. The bio-climatic chart for residential buildings and the space of simple solutions for the thermal comfort design strategies.

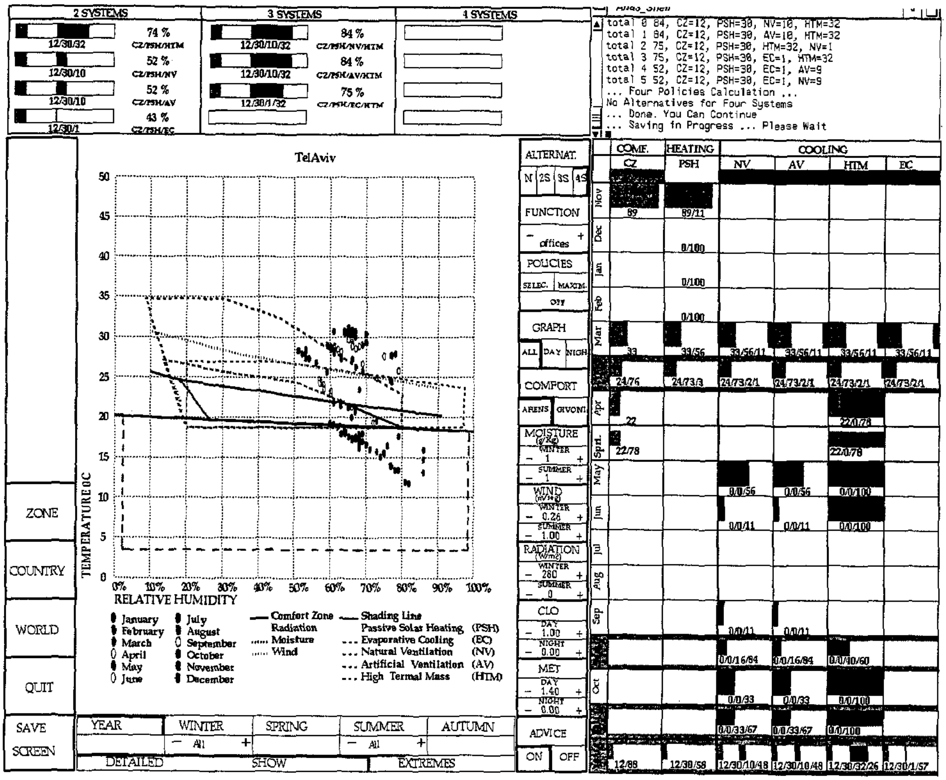


Fig. 3. The bio-climatic chart for an office buildings and the space of simple and complex solutions for the thermal comfort design strategies.

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