DAMP-EXPERT
EXPERT SYSTEMS BASED DAMPNESS DIAGNOSIS

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ABSTRACT

The goal of DAMP-EXPERT is to assist trained staff members with less experience regarding building fysics, in diagnosing dampness in buildings. DAMP-EXPERT is specially aimed at technical personal of housing corporations, local authorities and maintenance and renovations construction companies.
After an initial phase which was based on 'if-then' rules, a frame-based approach was chosen. For this implementations the HT (Hypothesize-and-Test) module of the KES expert system shell was chosen. KES-HT is based on abductive reasoning and implemented as 'descriptions' of dampness problems in terms of characteristics. In general seven main categories of dampness problems are recognized, devided into 50 detailed dampness descriptions.
Early 1990 the final phase of DAMP-EXPERT has started. This phase largely focusses on the user interface, which should accomodate the end user in his normal working practice. Also a module will be developed to cope in detail with the complex relationship between damp production, ventilation and temperature. In addition full text and hypertext.modules will be developed for extended explanation, terminology and building defects.

1. INTRODUCTION

Dampness is one of the major problems of the indoor environment. The mechanism which causes dampness problems is rather complex. Technical staff of housing corporations and property owners have to cover a wide range of expertise concerning building maintenance. The necessary expertise to diagnose dampness problems correctly is not always available. Especially for the more compex cases this lack of expertise often results in an incomplete, if not wrong diagnosis.
Already in 1982 Lansdown (1) investigated the application of expert system in the building and construction industry. Following the general trend of computer science introductions in the construction industry, however, it would take many years before expert system research results emerged (2 – 6). One of the first examples was BREDAMP (7), which was developed in 1985 and 1986 for the British Building Research Establishment (BRE) by Loughborough University. During the development of DAMP-EXPERT, we also came across two other dampness expert systems: DAMP (8) from New Zealand and AIRDEX from America (9). With BREDAMP a general

trend was followed which emphasized the development of advisory and diagnostic systems as a major application area for expert systems.
Together with the demonstration project for an expert system for fire safety design (10), DAMP-EXPERT was one of the first expert systems project at TNO-IBBC, initiated in 1986.

2. EARLY STAGES OF DAMP-EXPERT

During the CIB World Congress in 1986 the idea emerged to investigate the possibilities for a Dutch version of the British BREDAMP. During the rest of 1986 and early 1987 a feasability study was carried out if such a 'translation' to the Dutch situation could be realised. The result of this study was that BREDAMP differs too much from the Dutch situation regarding both scope and use.
After the summer period of 1987, the actual research started. Although some experience was available on the artificial intelligence language Prolog, it was decided that experience with an expert system shell would also be of importance. After some consideration the expert system shell KES was chosen. It is important to realise that early 1987 most of the present expert system shells did not exist yet. One of the reasons for chosing KES was that, already in those days, KES was available on a wide range of machines, including DOS (end users) and UNIX (internal use). KES is still being marketed and with the new 2.6 version it will be one of the first to support X-windows. The PS-module of KES is based on 'if-then' rules in combination with frames and forward chaining.
In June 1988 the first prototype was finished, based on four phenomena: condensation, hygroscopicity, leakage and capillarity flow. This version recognizes a preliminary diagnosis and a detailed diagnosis. During the evaluation, the initial dampness diagnosis indication was quite satisfactory. The detailed diagnosis, however, proofed to be inadequate from as well the 'depth' of dampness knowledge as towards the operational conclusion for the user.

3. FRAME BASED APPROACH FOR DAMP-EXPERT.

To be more recognisable for the user the number of dampness problems was broadened to seven main phenomena: surface condensation; interstitual condensation; hygroscopicity; rain penetration; raising damp; initial moisture contents, capillarity flow and leakage. More important, however, was that a more 'knowledgeable' reasoning towards dampness would not only be difficult in implementing, but more important, would be extremely difficult to maintain. It would be necessary to broaden the reasoning by creating more if-then rules. Much more complicated, however, would it be to fine tune the diagnosis, i.e. exceptions should be implemented, which would require a fast increasing number of if-then rules. Although we did not pursue this effect in detail, effects of combinatory explosion were envisioned.
It was therefore decided to explore the possibilities of the KES-HT module. HT (Hypothesize-and-Test) is based on abductive reasoning (11). The HT approach is based on describing each possible conclusion as a hypothesis, i.e. a particular

diagnosis. These hypotheses consist of a number of charateristics which should (or should not) occur. KES-HT will start generating questions which will be most effective in pruning the number of hypotheses. If for one of the hypothesis the characteristics does not match the description, HT will skip that particular hypothesis and the group of possible hypotheses will become smaller. At the end HT will generate a set of matching hypotheses. Depending on how good the user input matches these hypotheses, the matching hypotheses will be ranked in order of matching with an certainty value of high, medium or low.
During the first few months of 1989 various methods of generating HT descriptions were investigated. Initially seperate tables were produced for the two characteristics location and outer appearance. Horizontal the seven dampness problems and vertical the various values for both location and outer appearance. In the various cells factors were given in terms of probability (++, +, 0, -, --) regarding the relation between a certain hypothesis, i.e. a dampness problem, and a specific location or outer appearance.
This approach, however, did not offer satisfactory results regarding the precision of the question inference. This precision problem especially occures where the probability of a certain hypothesis depended on the overall location of the dampness problem within the building, e.g. ground floor or top floor. To accomodate this distinction it would be necessary to differ the hypothesis also on the basis of general location. To achieve this the seven main dampness problems were differentiated into more then 50 detailed dampness hypotheses. The results of phase-2 are described in the final report for phase-2 (12). An example of an KES–HT description as is implemented at present might look like:

```
surface condensation massive external wall [description:
    location = external wall <a>;
    outer appearance = stains, mold <h>, discoloring <l>;
    thermal bridges = true <n>;
    wall = concrete <h>, masonry <h>;
    isolated = false <a>;
    damp production = yes <h>, no <l>;
    operating ventilation system = yes <l>, no <h>;
    corners = true <h>;
    other locations = true <h>;
    ],
```

4. SPECIFIC SITUATIONS AND MULTI FUNCTIONALITY

During the development of phase-2 the idea emerged to high light a few specific dampness situations. These situations should be very distinct and well recognisable for the end user. If on the basis of a picture (fig.1) and an explanatory description such a situation was indeed indicated, it would not be necessary to start the detailed diagnoses process. However, if an additional detailed diagnosis was carried out the final diagnosis should include the specific situation, if only as one of more alternatives.

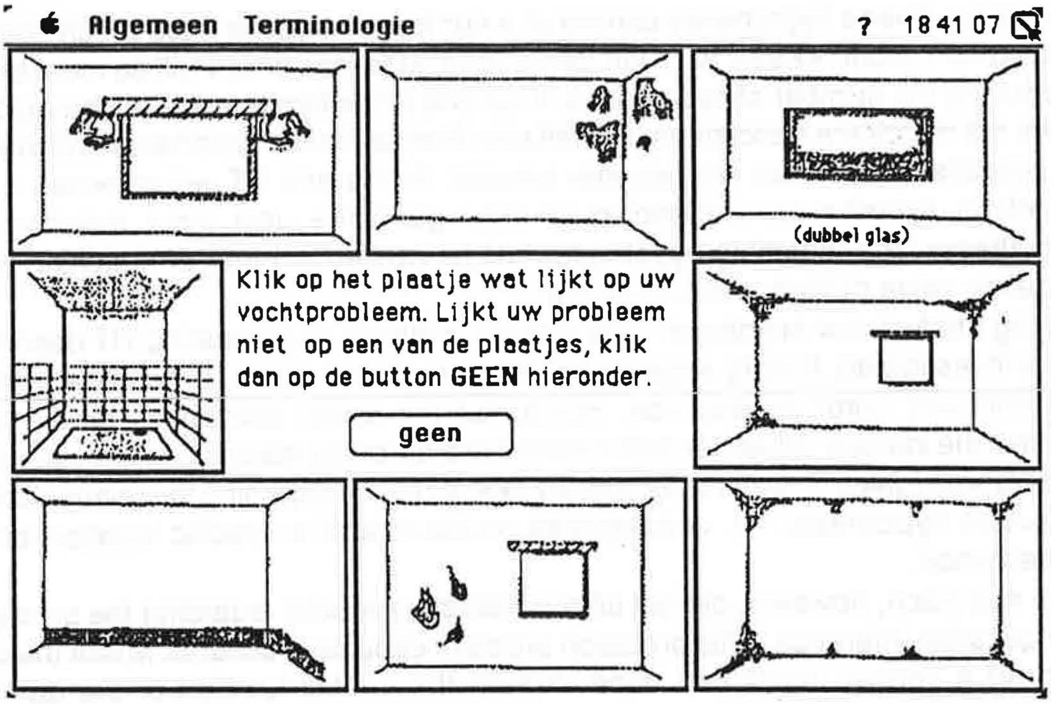

fig.1 Specific situations DAMP-EXPERT

Because dampness diagnosis is not an isolated process other views and considerations would be of importance for an acceptable DAMP-EXPERT system. Also in other expert system related projects at TNO-IBBC, this multi functionality proofed to be of importantce. For DAMP-EXPERT three added functionalities are being pursued:

- **Terminology.**
  Especially for less experienced users, it would be very helpfull if a quick reference mechanism would be available for checking the actual meaning of a term. During phase-2 a number of definitions were compiled and made accessible as a seperate module. In the final system these terminology definitions will be integrated in the system and may triggered at each opportunity. At present much attention is focused on terminology. The idea is that based on the international root thesaurus, Dutch translations will become operational. For specific applications, like DAMP-EXPERT, sub systems will be generated with the applicable terminology.
- **Extended explanation.**
  Regarding dampness much could and should be said about the various aspects of dampness. A publication which explains the topics covered in the DAMP-EXPERT system could very well be used as an independent supporting and/or explanatory document. During phase-2 the basis of such a document was implemented as a hypertext add-on, which could be consulted as a seperate module of the DAMP-EXPERT system. In phase-3 this module will be extended and integrated using a combination of full text retrieval and hypertext. At a number of questions the user may request '*extended explanation*', which will result in a jump to the appropriate page of the full-text/hypertext-module. Examples of publications which could be used for such an extended explanation are the new British Standards BS-8000 serie on workmanship (13), the SBR publication on energy concious construction (14) or the new version of the SBR 151 publication on dampness in buildings (15).

• **Building defects.**
The description of building defects is very common in the building industry. A good example are the *building defect action sheets* from the BRE. In a seperate feasability study (16) TNO-IBBC has implemented building defect descriptions in a full-text retrieval system. When dampness related 'defects' are compiled, it will be possible to access them from the DAMP-EXPERT system as is being finalised at present.

5. Diagnosis process DAMP-EXPERT

In December 1989 phase-2 has resulted in version–2 of DAMP-EXPERT, which recognises 5 steps (fig.2):
• Specific situations (A);
• Four initial questions regarding specific location, outer appearance, building type and general location (B);
• HT hypothesis inference, including the subsequent question generation (C);
• Additional reasoning concerning surface condensation. This part is directed towards the effects and influence of damp production, temperature and ventilation (D) ; and
• Detailed hypothesis explantion and possible solution startegies (E).

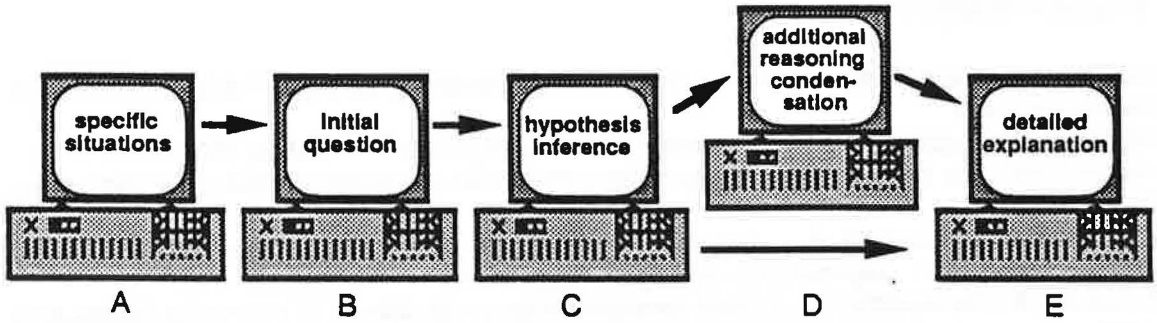

fig. 2 Diagnostic process DAMP-EXPERT

6. Final phase DAMP-EXPERT

Early 1990 the final phase-3 of DAMP-EXPERT has commenced. The aim of phase-3 is to implement the end user interface. This will done by creating an embedded C version of the KES-HT knowledge base together with the window package Vermont Views. During this phase workshops will be organised with potential end-users, to discuss the actual wording of the questions and the understandability of the answers. As part of phase-3 also an additional reasoning module will be developed to cope with the complex relationship between damp production, temperature and ventilation. This module will only be activated if surface condensation is part of the final diagnosis. Also the hypertext and full-text software for the modules for terminology, extended explanation and building defects will be implemented. For the end user a DOS version of DAMP-EXPERT will become available. For internal use and for online experiments, an UNIX core version will be implemented.

If the results of phase-3 are favourable it will be possible to have a beta version of DAMP-EXPERT available before the end of 1990. An actual commercial version will depend on an agreement regarding licence, support and maintenance.

6. Acknowledgement

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