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Behaviour based techniques in user adaptive Kansei technology

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Abstract. Application of behaviour-based control structures in Kansei technology gives a simple way for handling user adaptivity in emotion-based systems. One view of behaviour-based control systems is a kind of strategy reconfiguration – an intelligent adaptation of the system to the actual situation, by discrete switching to the most appropriate strategy, or a kind of fusion of the strategies appeared to be the most appropriate ones in an actual situation. Considering the actual user to be the actual situation, and the existing user models to be the different strategies, gives a clear connection between the user adaptability of the emotion-based systems and the situation adaptability of the behaviour-based control systems. Having more user models, the application of behaviour-based control structures can add user adaptivity to existing emotion-based systems simply by fusing the existing human opinions in the function of the approximated similarity of the actual user opinions to the existing models. For introducing a possible application area of the proposed structure, a user adaptive emotion-based (Kansei) furniture selection system application is introduced in this paper.

1. Introduction

One of the key goals of the emotion-based systems is to build the Kansei user model, the relation of the user emotion related requests (like “friendly” or “convenient”) and the physical parameters characterising the objects to be selected. One of the difficulties of building this relation is the highly user dependent interpretation of the physical meanings of the same emotional word. In most cases the same emotional word for different users covers very different physical interpretations. Many systems applied the Kansei technology are not handling this problem. They have only one fixed Kansei user model, generated off-line, based on a wide user inquiry, as a statistical average of the different answers [1,2]. Nowadays there is a lot of work related to the on-line user adaptivity of the Kansei user model. Some of these works applying learning methods to modify a global user model based on the on-line interventions, or interactions of the actual user [3,4,5]. We think, that there are some chance of having situations, there modifying only a small region of the user model (as a part of the on-line adaptation) can lead to incoherence (in sense of the consistency, or locality of the modification) of the user model.

Solving the problem of the probable occasional incoherence, and to give a simple way for implementing user adaptivity, in this paper we suggest to adapt behaviour-based strategy fusion (in this case user model fusion) techniques for emotion-based systems. The main benefit of the proposed behaviour-based structure application, that it achieves user adaptivity by fusing some fixed existing (off-line collected) user models. This fusion is done globally in the manner of “more similar the actual user to one of the existing user models, more similar must be the actual user model to that user model". Supposing, that all the off-line collected user models are appropriate, and the fusion (combination) is affecting coherently the entire user model, we hope, – that the global combinations of the valid user models are also valid user models – that we can avoid the above mentioned accidental incoherence.

2. Behaviour-based control structure for adaptive Kansei user model

In behaviour-based control systems (a good overview can be found in [6]), the actual behaviour of the system is formed as one of the existing system behaviours (which fits best the actual situation), or a kind of fusion of the known behaviours appeared to be the most appropriate to handle the actual situation. A different view of the same problem is a kind of situation adaptive strategy reconfiguration. The main idea of this view is the following: "The more similar the actual situation to one of the known partial strategy prerequisites, the more similar the strategy used to that strategy must be". Considering the actual user to be the actual situation and the existing user models to be the different strategies, it is very easy to adapt the behaviour-based control system structure for user adaptability in emotion-based systems. Having more user models, we can achieve user adaptibility simply by fusing them in the function of the approximated similarity of the actual user opinions to the existing models.

The application of the strategy reconfiguration structure has two main tasks. The first is a decision about the levels of necessities of the different strategies (user models in this case); the second is the way of the strategy (user model) fusion. The first task can be viewed as an actual system state approximation, where the actual system state is the approximated level of similarities of the actual situation (user in this case) to the prerequisites of all the known strategies (to the existing user opinions, the level of necessity of the existing user models needed to form the actual user model). The second is the fusion of the existing strategies (user models) based on these similarities. For the first task, we suggest the adaptation of finite state fuzzy automata, where the state variables are the corresponding similarities, and the state-transitions are driven by fuzzy reasoning (State Transition Rulebase on fig.1.). For the second task, the application of interpolative fuzzy reasoning is suggested. Having the approximated similarities of the actual user to the existing user models, the existing user models can be simply combined as an upper level interpolative fuzzy reasoning in a function of the corresponding similarities to get the actual user model (Interpolative Fuzzy Reasoning on fig.1.).

2.1 System state (actual user similarity) approximation

For the system state (actual user similarity) approximation a fuzzy automata is adapted. Its actual state (actual similarities, see fig.1.) is a set of similarity values, the actual approximated similarities of the actual user and the existing user opinions (Kansei Descriptor sets on fig.1.). The state-transitions of the fuzzy automata are driven by fuzzy reasoning (Fuzzy State Transition Rulebase on fig.1.) as a decision based on the previous actual state (Actual Similarities on fig.1.) and the similarities of an editing actual user opinion to the existing user opinions (Similarity Calculations on fig.1.). Practically, in our sample application the modification of the actual similarities is done during the editing state of the selection system - this could be invoked any time of the selection process. It means, that the actual user can modify the actual similarities (state) by giving his/her opinions related to the actual object (Edited Furniture on fig.1.). Based on the similarities of this opinion to the existing user opinions (Similarity Calculations on fig.1.), and based on the previous state, the new actual state (similarities) is calculated by the state transition Fuzzy Reasoning (using the State-transitions Rulebase (fig.1.)).

The rulebase applied for the state-transitions of the fuzzy automata (rules for interpolative fuzzy reasoning) for the i[th] state S_i ($\mathbf{R}_{Ai}$): (1)

If S_i=One **And** SS_i=One **Then** S_i=One
If S_i=Zero **And** SS_i=Zero **Then** S_i=Zero
If S_i=Zero **And** S_k=One **And** SS_i=One **And** SS_k=One **Then** S_i=Zero
If S_i=One **And** SS_i=Zero **And** SS_k=Zero **Then** S_i=One
If S_i=Zero **And** S_k=Zero **And** SS_i=One **And** SS_k=Zero **Then** S_i=One

where SS_i is the calculated similarity of the actual user opinion to the i[th] existing user opinion, $k \in [1, N], k \neq i$.

The structure of the state-transition rules is similar for all the states. The reason of the interpolative way of fuzzy reasoning is the incompleteness of state-transition rulebase [7].

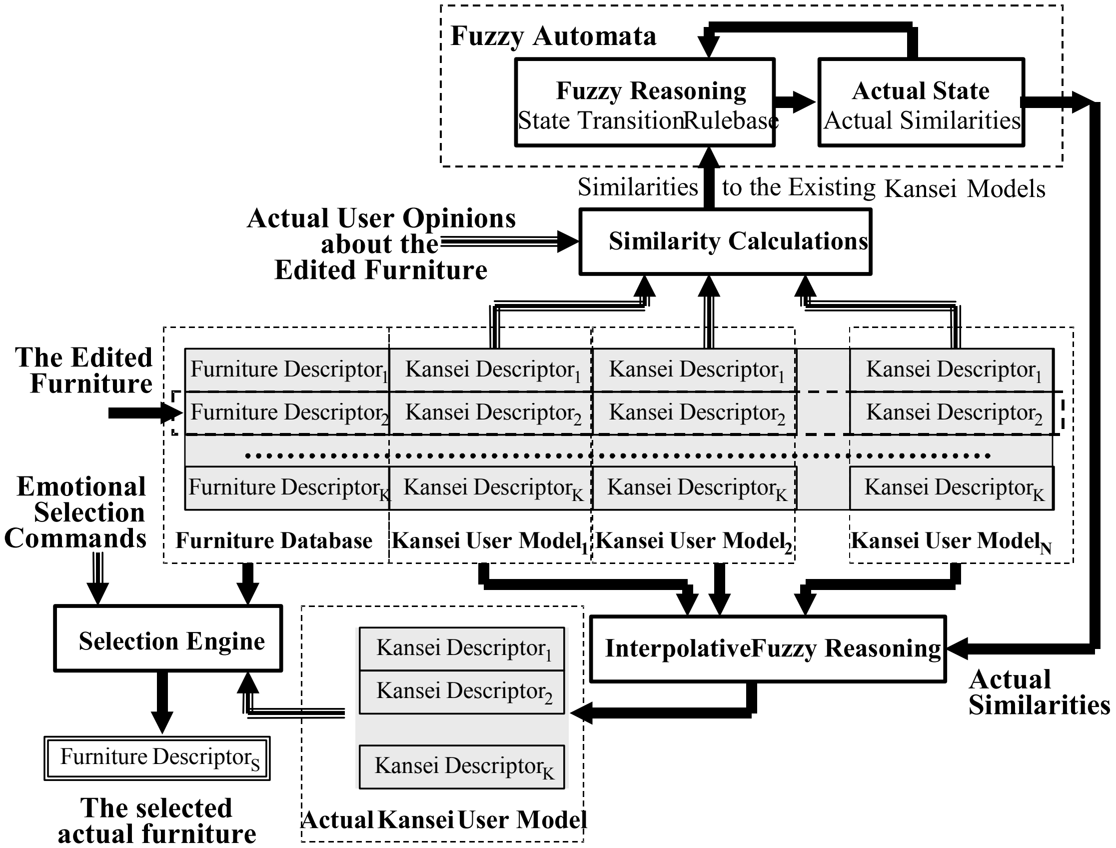

Fig.1. Structure of the proposed adaptive Kansei user model generation

2.2 User model fusion

For the second task, for the fusion of the existing Kansei user models, we suggest to apply interpolative fuzzy reasoning. The actual Kansei user model is generated as a fusion of all the off-line collected user models. The simplest way for combining the existing user models in the function of the corresponding actual similarities, is the application of the interpolative fuzzy reasoning [8]. The main idea of the proposed adaptive Kansei user model generation is - “the more similar the actual situation to one of the known partial strategy prerequisites, the more similar the strategy used to that strategy must be” - can be directly translated to an interpolative fuzzy rulebase. (Applying interpolative fuzzy reasoning the completeness off the fuzzy rulebase is not necessary.) The rulebase applied for the interpolative fuzzy reasoning to combine the existing user models (sets of Kansei descriptors on fig.1.) in a function of the corresponding similarities is the following:

$$\begin{array}{llllll} \textbf{If } S_1=\text{One} & \textbf{And } S_2=\text{Zero} & \textbf{And} \ldots & \textbf{And } S_N=\text{Zero} & \textbf{Then } KD=KD_1 & (2) \\ \textbf{If } S_1=\text{Zero} & \textbf{And } S_2=\text{One} & \textbf{And} \ldots & \textbf{And } S_N=\text{Zero} & \textbf{Then } KD=KD_2 & \\ & \ldots & & & & \\ \textbf{If } S_1=\text{Zero} & \textbf{And } S_2=\text{Zero} & \textbf{And} \ldots & \textbf{And } S_N=\text{One} & \textbf{Then } KD=KD_N & \end{array}$$

for all the Kansei descriptors in a user model, where KD_i is the set of Kansei descriptors in the i^{th} user model, and KD is the set of Kansei descriptors of the actual Kansei user model we are searching for.

Comments: instead of interpolative fuzzy reasoning a kind of weighted average (where the weights are functions of the corresponding similarities) is also applicable (even it is not so flexible in some cases).

The goal of the actual Kansei user model modifications from the actual user side is to tune the system to be closer to his/her opinions. Practically the system is starting from an initial state (where the similarities to the existing models are equal), and in the case the user is disagree with the evaluation of the actual object (furniture) given by the system, he/she has the possibility to modify the actual user model by giving his/her opinions. In most cases the given opinions are related to one or a few Kansei descriptors of the edited object (furniture in our case). But because of the proposed structure, all the changes are done globally (all the Kansei descriptors of an existing user model has the same weights "globally" in the actual model – not only the descriptor weights related directly to the given user opinion are "locally" modified). We hope that this kind of adaptation strategy keeps the actual user model coherent. E.g. if one of the users have exactly the same opinions as one of the existing user model (even his opinions were given through a few Kansei parameters only), then (after a few modification, detection steps) as the best fitting existing user model, the system will use it exactly. In case of having more partially different existing user models fitting exactly the given user opinions, then the actual user model is formed from their fusion.

3. Example application - User adaptive furniture selection

As an example of the proposed behaviour-based control structure application a user adaptive emotion-based (Kansei) furniture selection system application was developed (see fig.2.). The goal of the selection system is to aid furniture (chair) selection by giving the chance to the user to express his/her requirements through emotional (Kansei) levels. The set of handled emotions is fixed to 16 emotional words related to chairs. The user is giving the requirements by selecting some of the emotional words and adjusting the corresponding sliders. On the sliders the "+", "0", "-" symbols are appearing only, to inspire the user to give his/her feelings in a scale-less manner (see fig.2.).

As a response of the user intervention, the best fitting chair is appearing in the working window. The same time the system gives all the Kansei values (16 in our case), related to the furniture on screen, fetched from the actual Kansei user model. These values are appearing the same manner, on sliders (side by the user sliders, see fig.2.), as the user was giving his/her requirements. This method inspires the user to make modifications in more/less, small/big differences manner – relative to the furniture on screen.

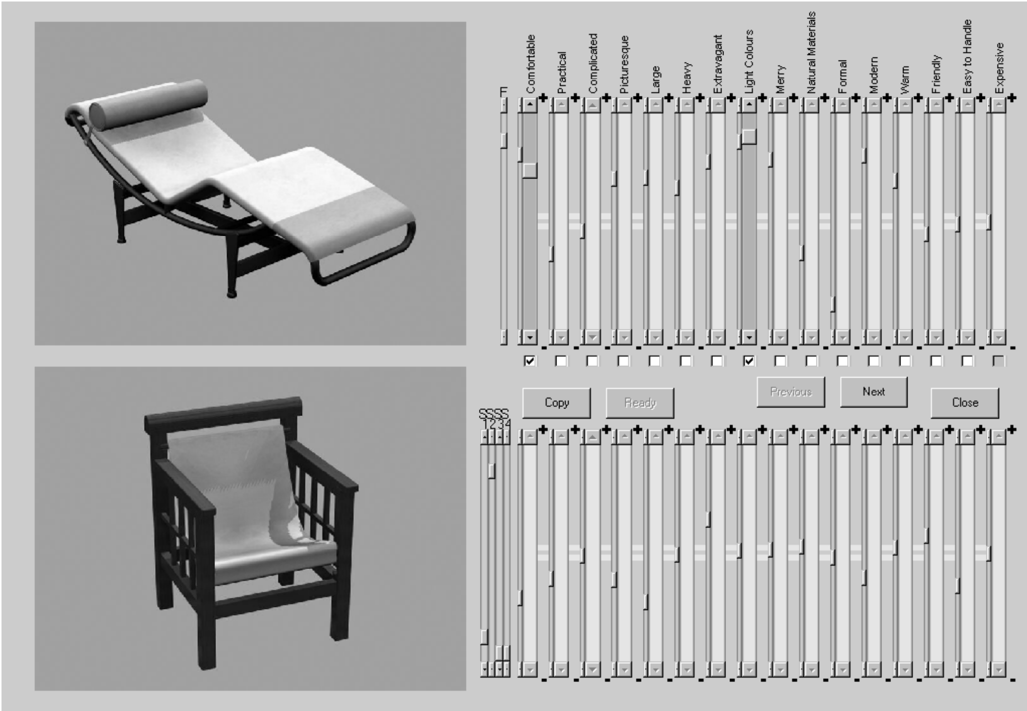

Fig.2. Screenshot of the furniture selection system

3.1 The Kansei user models

The existing Kansei user models were generated based on questionnaires. Some persons (as a small example - four in our case) were asked to give their opinions about chair pictures. The inquired persons had to make a partial ordering of a set of pictures of 43 different chairs. For each emotional (Kansei) attributes in the questionnaire, the inquired persons were first asked to make a rough order of the pictures into seven groups: very ~, ~, a little bit ~, ? (indifferent), a little bit not ~, not ~, very not ~ - where ~ is the actual Kansei attribute. Than he/she was asked to partially order the pictures of the same groups. (Partially ordering was meant ordering in the case if the pictures are distinguishable with respect to the Kansei attribute, and signing equality, if they are indistinguishable.)

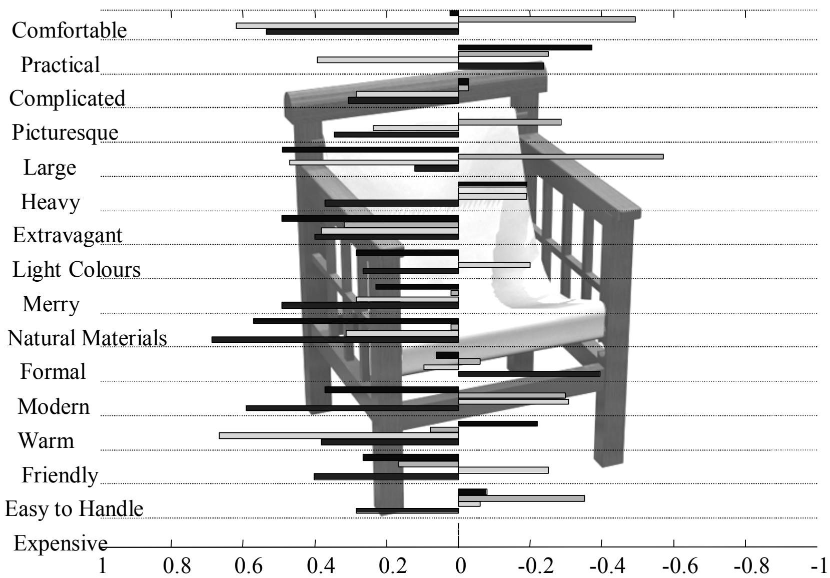

Fig.3. Different user opinions about the same furniture

The answers than translated to real values of the [-1,1] interval, according to equal width of the seven attribute group, and equal distances of the elements of the same group in the manner of partial ordering (equal values for the indistinguishable ones). These values are forming the Kansei descriptors. The Fuzziness of the Kansei descriptors is characterised by constant scaling function [9] (like similar isosceles triangle shaped fuzzy sets). All of these values for all the emotional attributes are forming the Kansei user model.

As we had a sample application only, there were a small query made, only four persons were asked about their opinions. As a result we get four existing Kansei user models. See an example of the different ranking of the same chair with respect to 16 different Kansei attribute of four persons we asked on fig.3.

3.2 The selection system

According to the proposed structure on fig.1., our system has four Kansei user model (four set of Kansei descriptors - values characterising the human feelings related to the database elements) and a set of furniture descriptor – picture, or CAD description of a furniture (picture in our case). The actual Kansei user model is generated as the fusion of the existing Kansei user models based on the actual similarities, by interpolative fuzzy reasoning (as it is proposed in section 2., using the rulebase (2)). The initial value of the actual similarities (initial state of the fuzzy automata) is a vector of 0.5.

A selection engine (see Selection Engine on fig.1.) does the actual selection. The task of the selection engine is to select the furniture descriptors from the furniture database, which have the closest actual Kansei descriptor to the user requirements. The similarities are calculated as distances in Euclidean sense. Having a user selection command, the best fitting (closest) furniture is put on screen. Then the user can use the Next (Previous backward) button to view the next best fitting furniture (fig.2.).

The same time as the furniture appearing on the screen, the system shows its Kansei descriptors (fetched from the actual Kansei user model). These values are appearing the same manner, on sliders (side by the user sliders, see fig.2.), as the user was giving his/her requirements. In the case the user is disagree with the evaluation given by the system, he/she can give his/her opinions by copying the actual furniture to the editing window (bottom of the screen on fig.2.) and adjusting some of the bottom sliders. Pressing the Ready button, the system recalculates the actual similarities (as it was introduced in the 2. section). The similarities (SS_i) of the given user opinions and the ith existing Kansei user model is calculated using the following formula (applying functions of the Fuzzy c-Means fuzzy clustering algorithm [10]):

$$SS_i = \frac{1}{\sum_{j=1}^{N} \left(\frac{d_i}{d_j} \right)^{\frac{2}{m-1}}}$$

where $d_k = \|\mathbf{x} - \mathbf{v}_k\|$, the distance (measure of dissimilarity) of the user opinions (Kansai descriptors) $\mathbf{x}$ and the Kansei descriptors of the edited furniture in the kth existing Kansei user model $\mathbf{v}_k$, m is a weighting exponent (usually m=2).

The fuzzy automata (as it is proposed in section 2.) is using the rulebase (1). Its initial state (initial value of the actual similarities) is a vector of 0.5.

3.3 Experiences

Checking the efficiency of the proposed structure, as it deals with emotional parameters, is not easy. At least for checking the ability of approximating the user opinions, we made a test user model set. These user models are containing only one Kansei descriptor and a single furniture. By the first user model, this furniture is very not ~, by the second a little bit not ~, by the third a little bit ~, by the fourth very ~. Running the actual user opinions through the universe [-1,1], as a step function (repeating the same requirements 10 times, than jump), we got the actual Kansei user model shown on fig.4. The notation of the figure is the following: KVUi is the i^{th} user model (only one Kansei descriptor), Si is the i^{th} element of the state vector (actual level of similarity to the i^{th} user model), Ureq. is the user requirement, and SysApprox is the actual Kansei user model (only one Kansei descriptor).

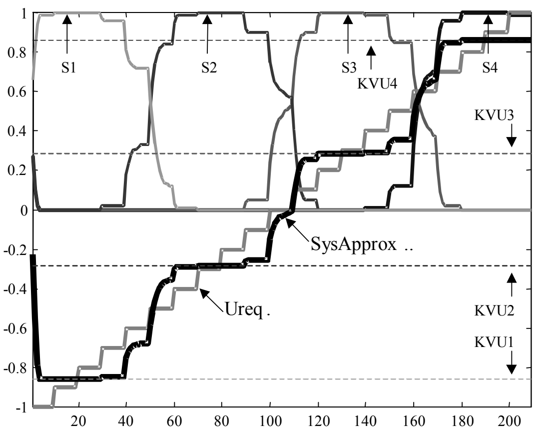

Fig.4. Test user model set, step user requirements.

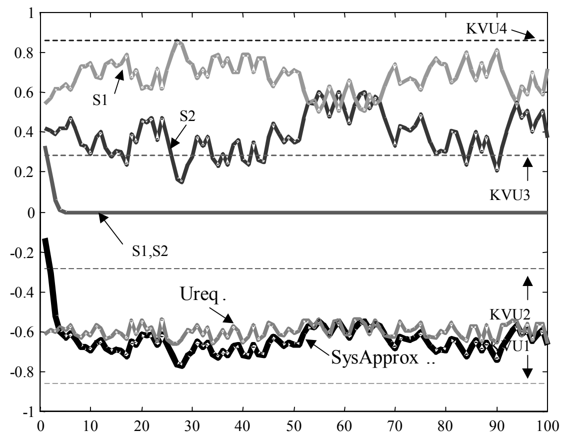

Fig.5. Test user model set, constant noisy user requirements.

For testing the robustness of the system against random noise, we used the above introduced test user model set. This case the input actual user opinion was a constant value superimposed with random noise. The actual Kansei user model we got this case is shown on fig.5. (The notation of the figure is the same as fig.4.) Repeating the first test (step function actual user opinions), using the real Kansei user model set, we got the result shown on fig.6.

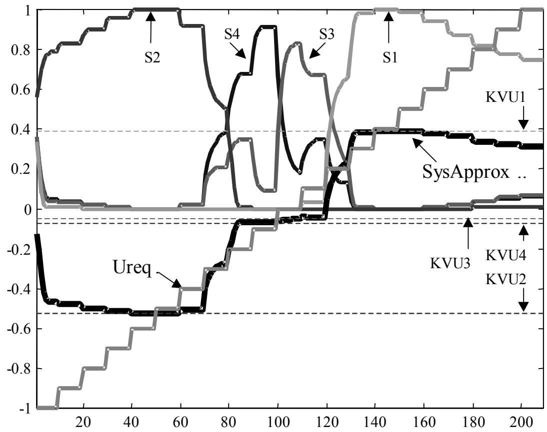

Fig.6. Original user model set, repetitive step user requirements.

4. Conclusion

The main benefit of the proposed behaviour-based control structure application in emotion-based (Kansei) systems is to give a simple way for handling user adaptivity. The main reason of these applications is the analogy between the situation (environment) adaptivity of behaviour-based systems and the user adaptivity of the emotion-based systems. E.g. the different existing user opinions can be fused the same manner (to be more suitable for the actual user) as it is done during the strategy fusion in behaviour-based solutions. This case the "adaptive knowledge" of the system related to the actual user is not a new adapted user model, but a set of approximated similarities, the similarities of the actual user to the existing user models. We hope that the application of behaviour-based control structures in emotion-based systems, the global similarity based combination of existing user models, is able to avoid incoherence could caused by step by step partial modifications of the user model during some kind of user adaptive solutions.

Because of the interpolative properties of the user model combination, the proposed structure is unable to follow user requirements outside the area covered by the existing user models (see e.g. on fig.6.). In other words, the system cannot go beyond its existing "knowledge". The only solution of this problem is extending the number and the variety of the existing user models.

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