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Fuzzy Reasoning and Fuzzy Automata in User Adaptive Systems

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Introduction

<u>Difficulties</u>: Control **partially known** complex systems.

<u>Solution</u>: Fusing partially valid control strategies in the function of their **suitability**:

Behaviour-based control structures

<u>An interpolative view</u>: "**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**."

Similarity based strategy reconfiguration

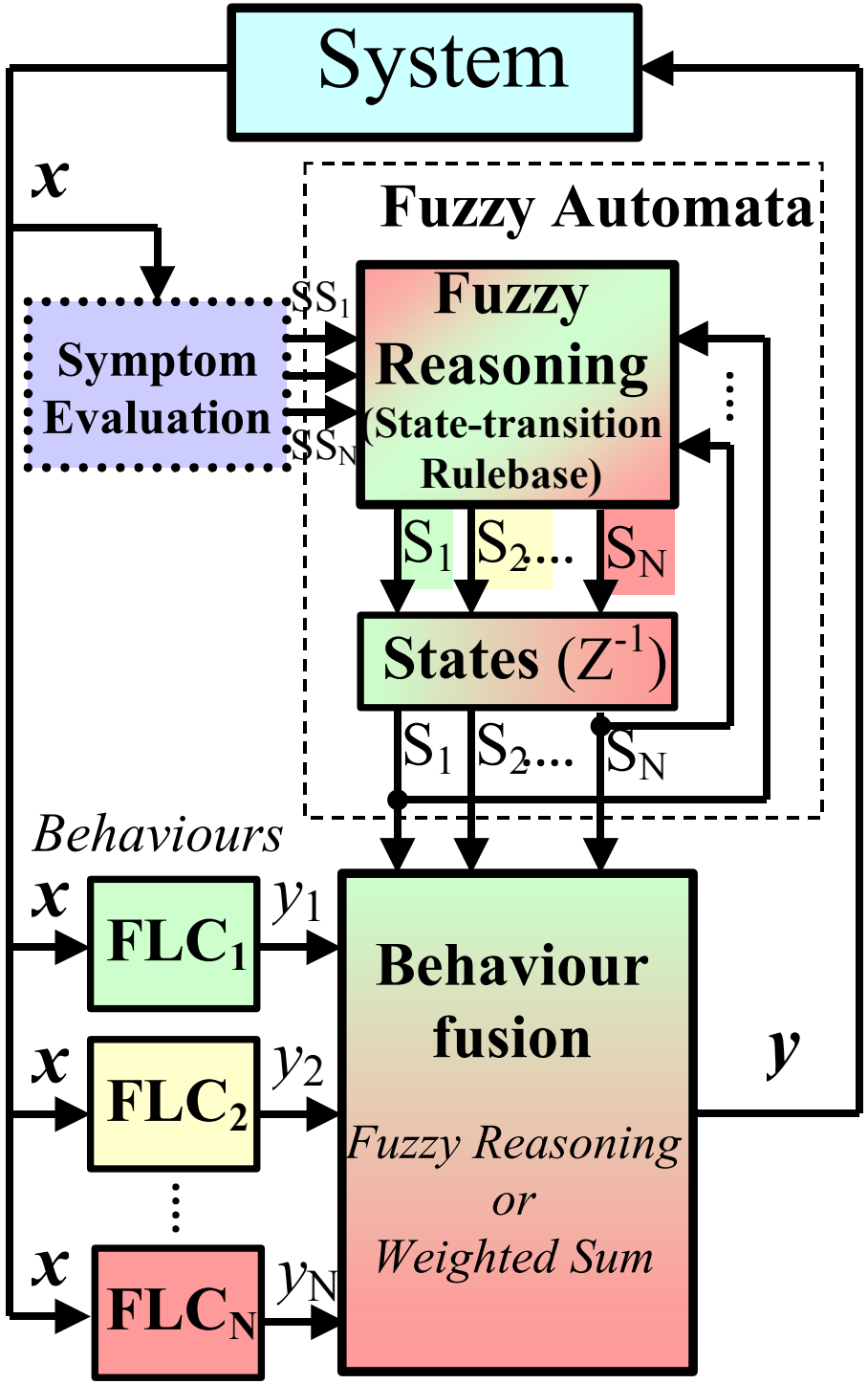
<u>The main tasks to solve</u>:

The actual system-state approximation*:* The actual system-state – the approximated level of similarities of the actual situation to the prerequisites of all the known strategies, *the level of necessity and the type of the strategy needed to handle the actual situation* – must be determined.

The fusion of the existing partial strategies*:* based on the approximated system-state - *in the function of their suitability* – the *conclusions* (proposed actions) of the known partially valid (component) strategies *must be fused*.

For the first task, the adaptation of ***fuzzy automata*** is proposed, where the state variables are the corresponding similarities, and the state-transitions are driven by fuzzy reasoning.

For the second task, the application of ***interpolative fuzzy reasoning*** is suggested.



Adaptive Behaviour-based Structure

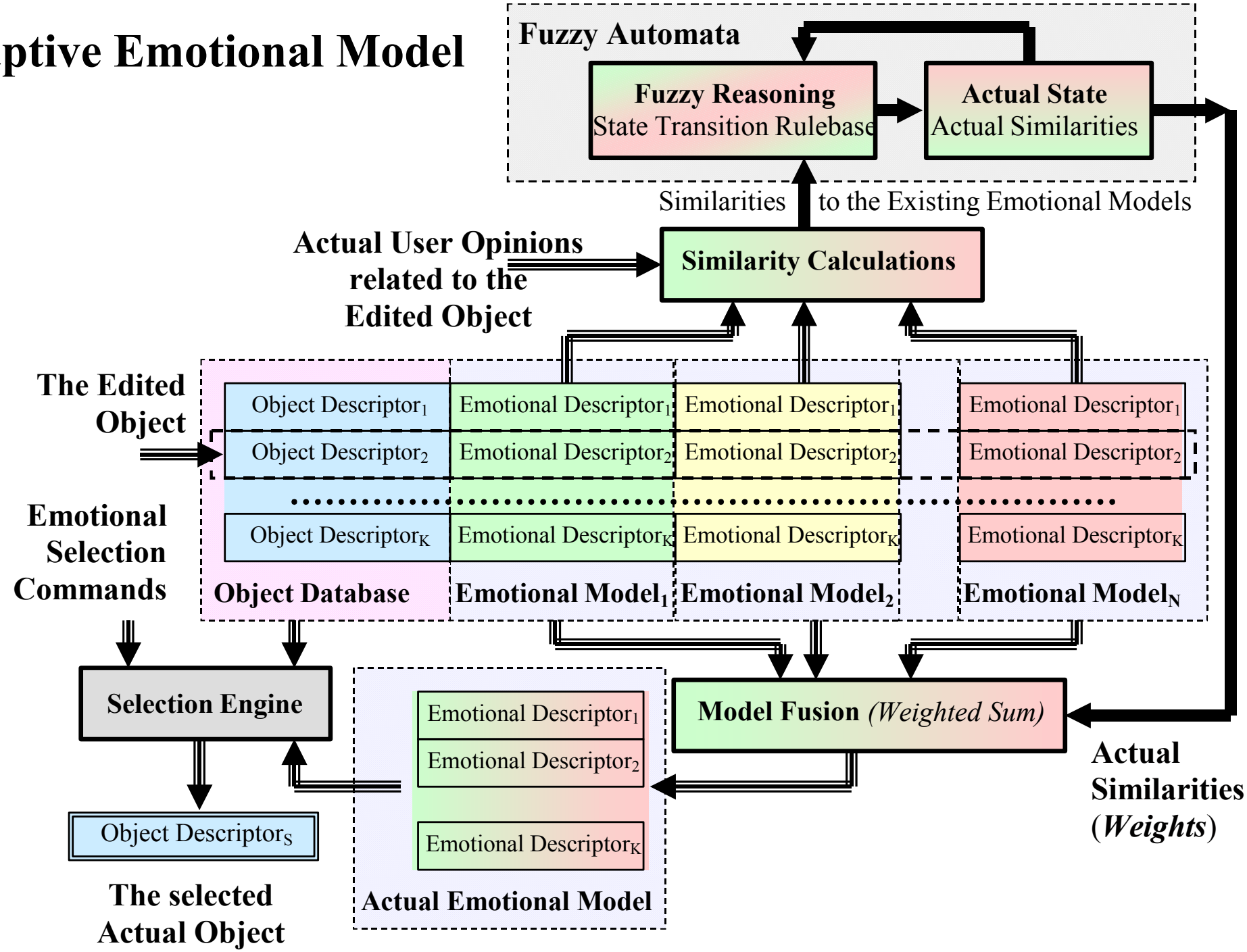
Adaptivity to the

– **current situation** (common behavioural-based applications), (***Identifying*** the ***situation*** in the manner of the ***available behaviours***)

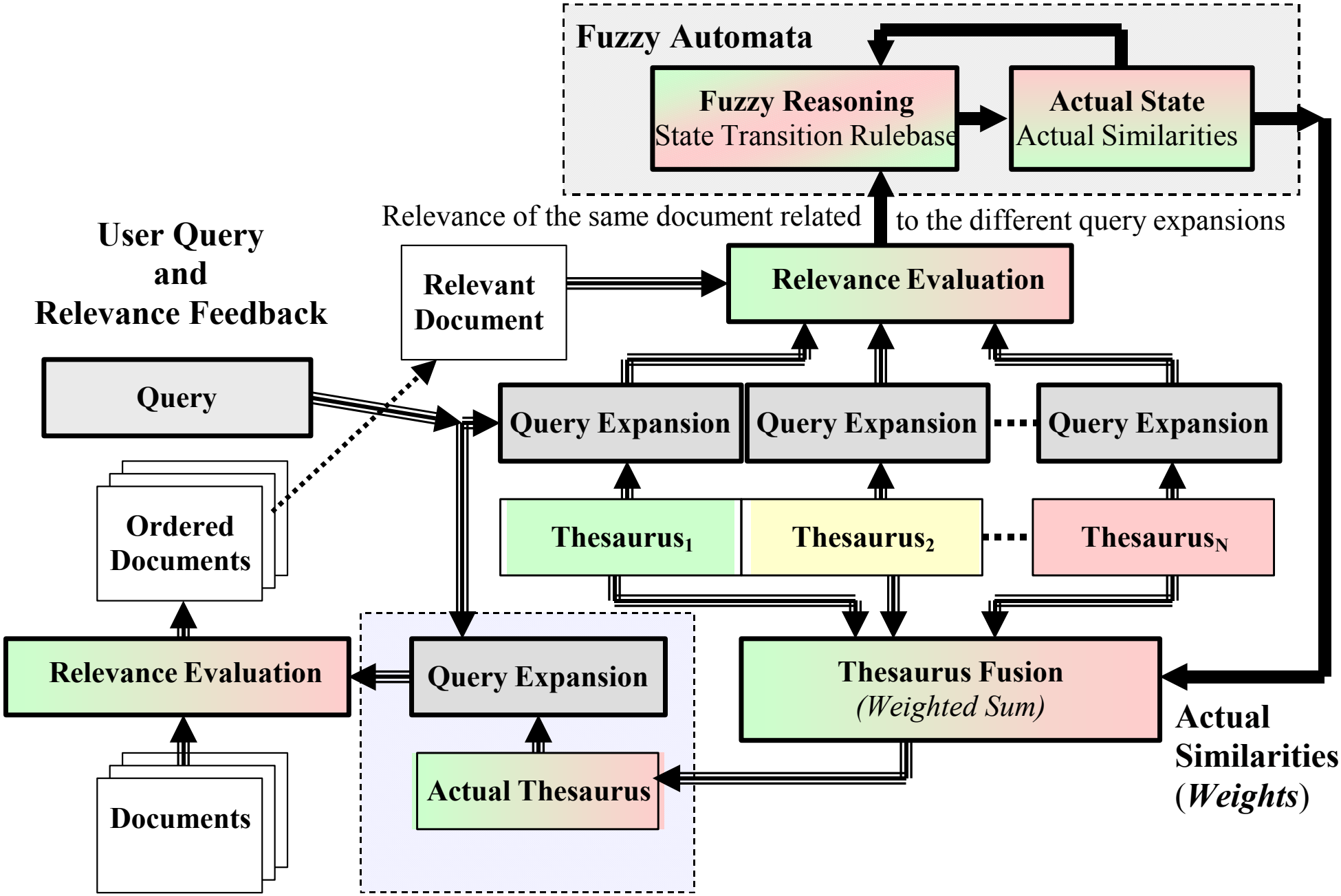
– or the **controlled system** itself (e.g. fault tolerant control applications), (***Identifying*** the ***system*** in the manner of the ***available controllers***)

– or even the **actual user** herself/himself (user adaptive systems). (***Identifying*** the ***user*** in the manner of the ***available user models***)

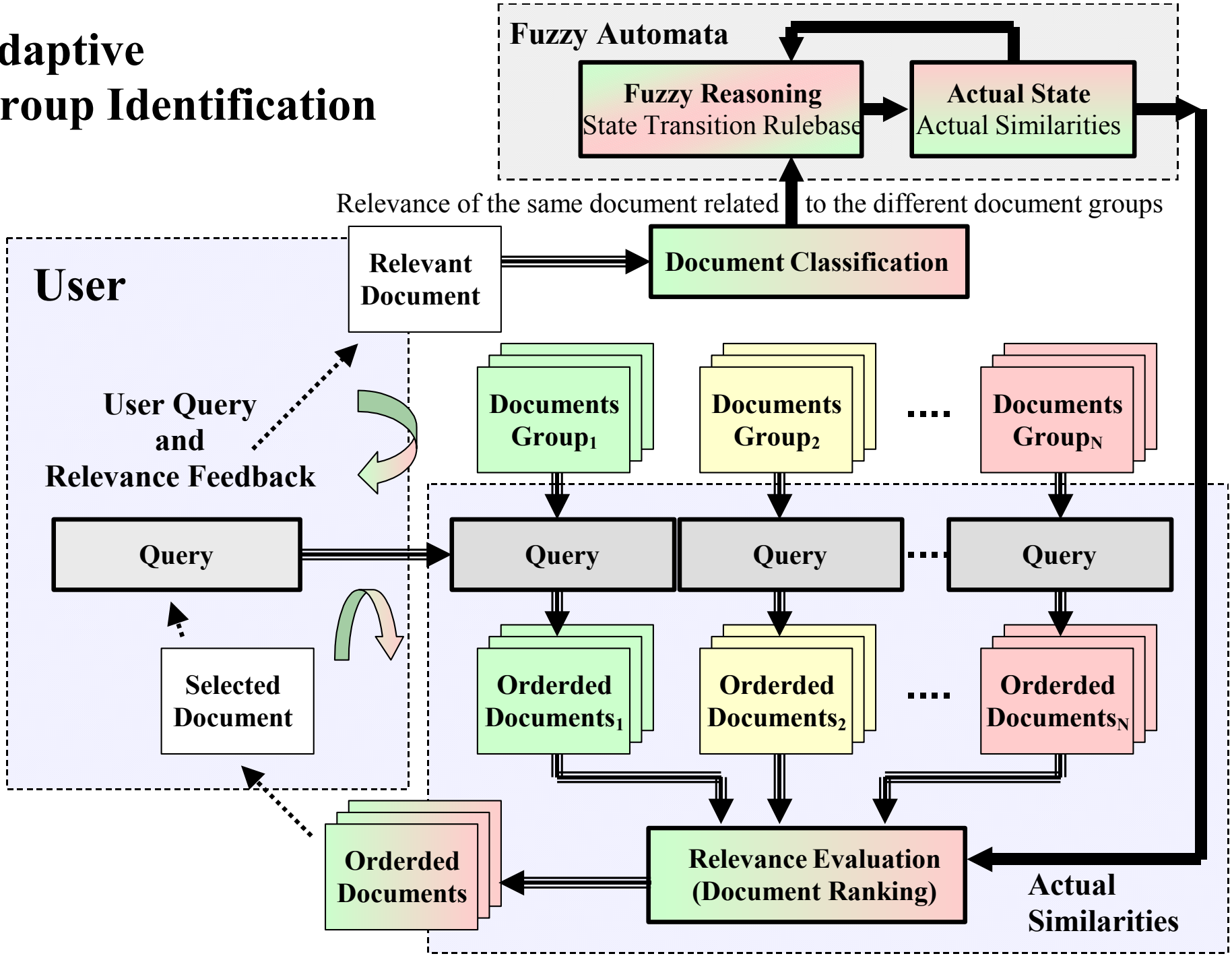
Adaptive Emotional Model



Adaptive Thesaurus



Adaptive Group Identification



User identification related to the existing models ⇒ Fuzzy automata

(Approximating the similarities of the actual user to the existing user models)

State: A **set of similarity values**, the actual approximated similarities of the actual user and the existing user models.

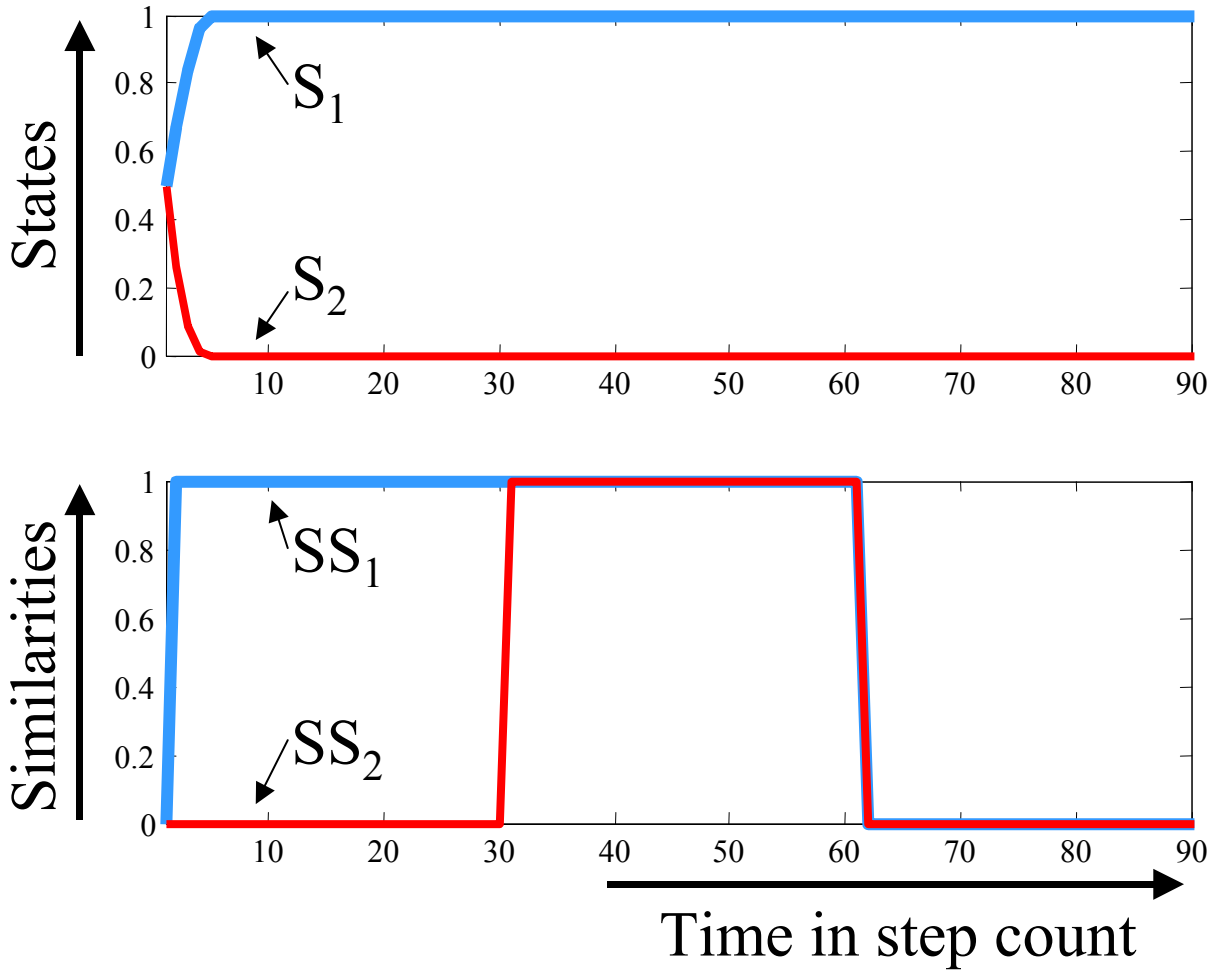
State-transitions: Are driven by **fuzzy reasoning** (**Fuzzy state transition rulebase**) as a decision based on the **previous actual state** (approximation) and the **similarities** of a **given user opinion** (*feedback*) to the **user models**.

State-transitions rulebase for the ith state variable S_i (R_{Ai}):

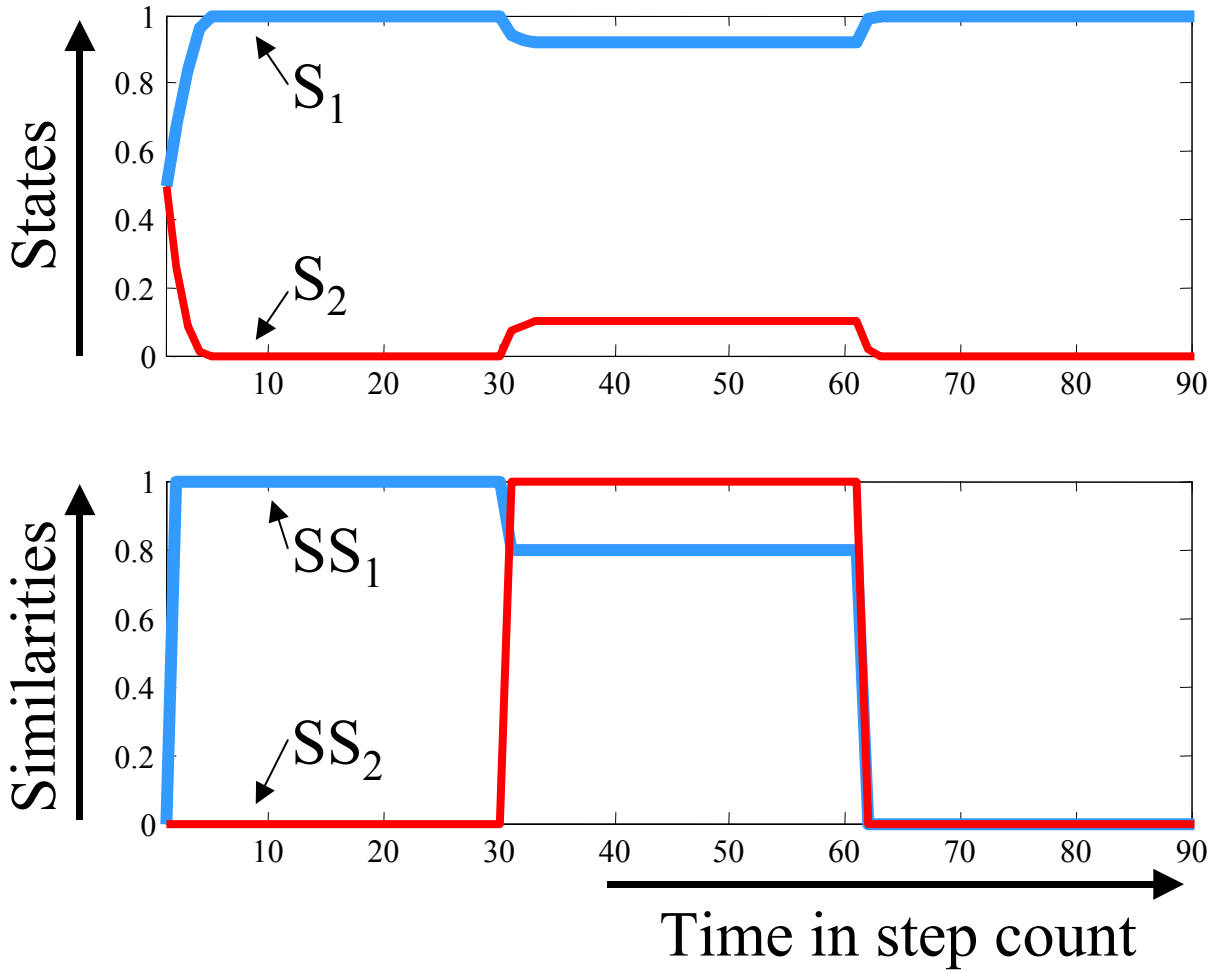
If	S_i=One	**And**	SS_i=One						**Then**	S_i=One
If	S_i=Zero	**And**	SS_i=Zero						**Then**	S_i=Zero
If	S_i=One	**And**	SS_i=Zero	**And**			SSk=Zero		**Then**	S_i=One
If	S_i=Zero	**And**	SS_i=One	**And**	S_k=Zero	**And**	SS_k=Zero		**Then**	S_i=One
If	S_i=Zero	**And**	SS_i=One	**And**	Sk=One	**And**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

where SS_i is the calculated similarity of a given user opinion to the ith existing user model, $k \in [1, N], k \neq i$. The structure of the rules is similar for all the states. (Incomplete rulebase - interpolative fuzzy reasoning)

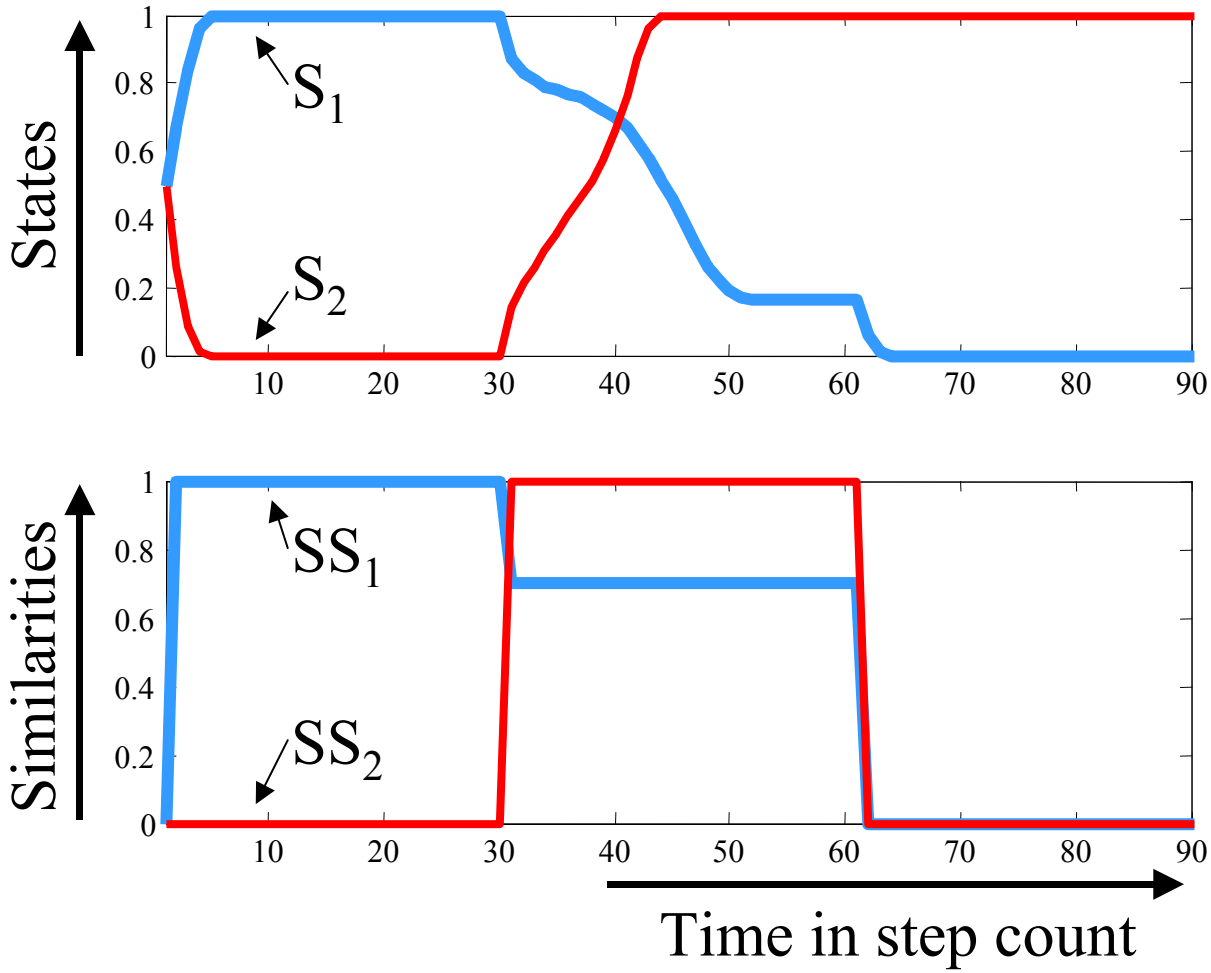
Don't "pick up" a new state (you already have a good one)



Don't "pick up" a new state (even it seems a little bit better)



Change if the previous is not satisfied and a better one exists



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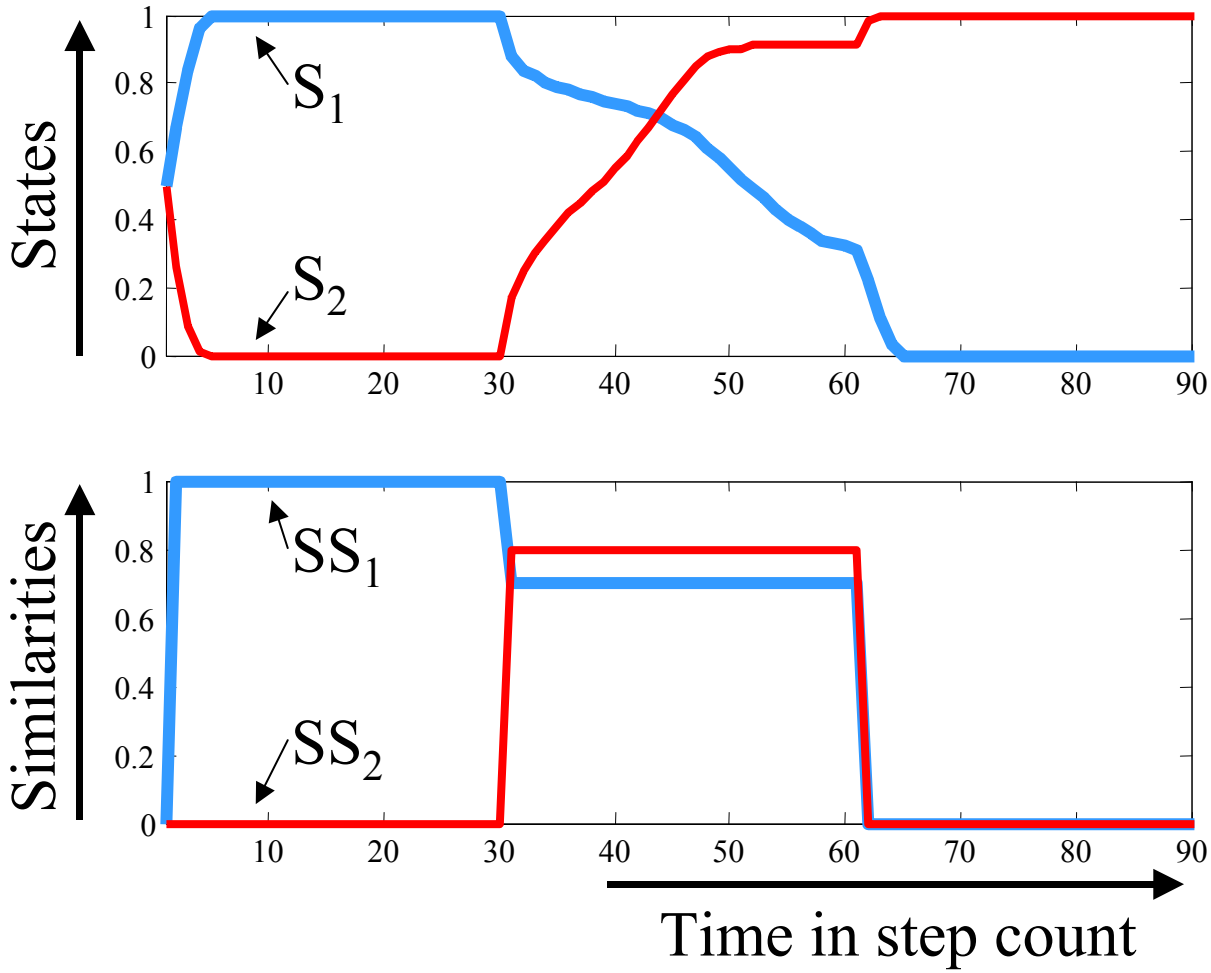
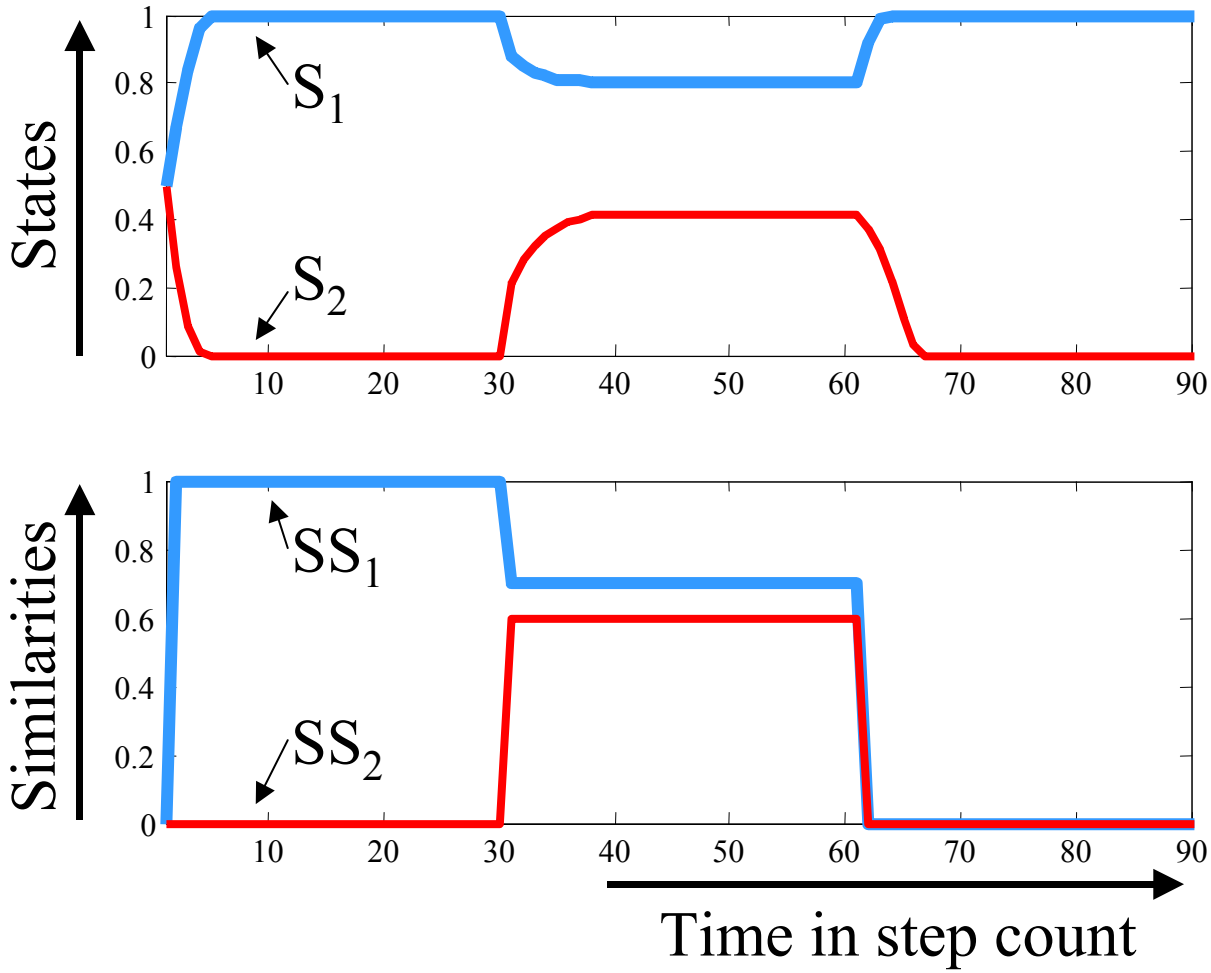
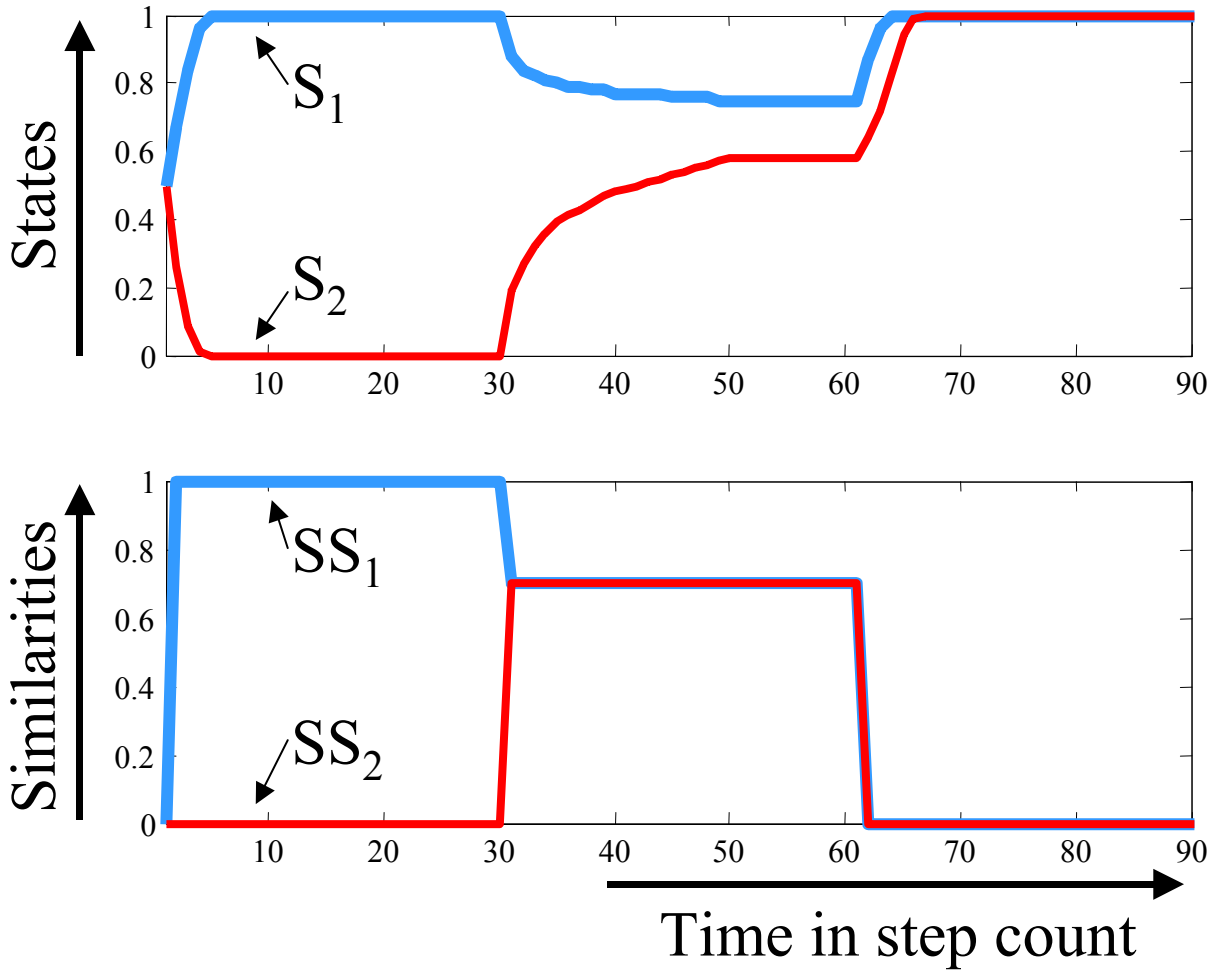


But don’t change if the new one is not really better



Even both could be good solution



Model Fusion

⇒ **Interpolative fuzzy reasoning** – (flexible)

⇒ **Weighted Sum** – (Simple)

Interpolative fuzzy reasoning:

```
If S1=One    And S2=Zero And ... And SN=Zero  Then y=y1
If S1=Zero   And S2=One  And ... And SN=Zero  Then y=y2
             ...
If S1=Zero   And S2=Zero And ... And SN=One   Then y=yN
```

Weighted Sum:

$$E_{i,j} = \frac{\sum_{k=1}^{K} w_k \cdot E_{i,j,k}}{\sum_{k=1}^{K} w_k}, \quad \forall i \in [1, I], \ \forall j \in [1, J], \ w_k = S_k, \ \forall k \in [1, N],$$

where $E_{i,j}$ is the matrix of the actual emotional model, $w_k = S_k$ is the kth model weight.

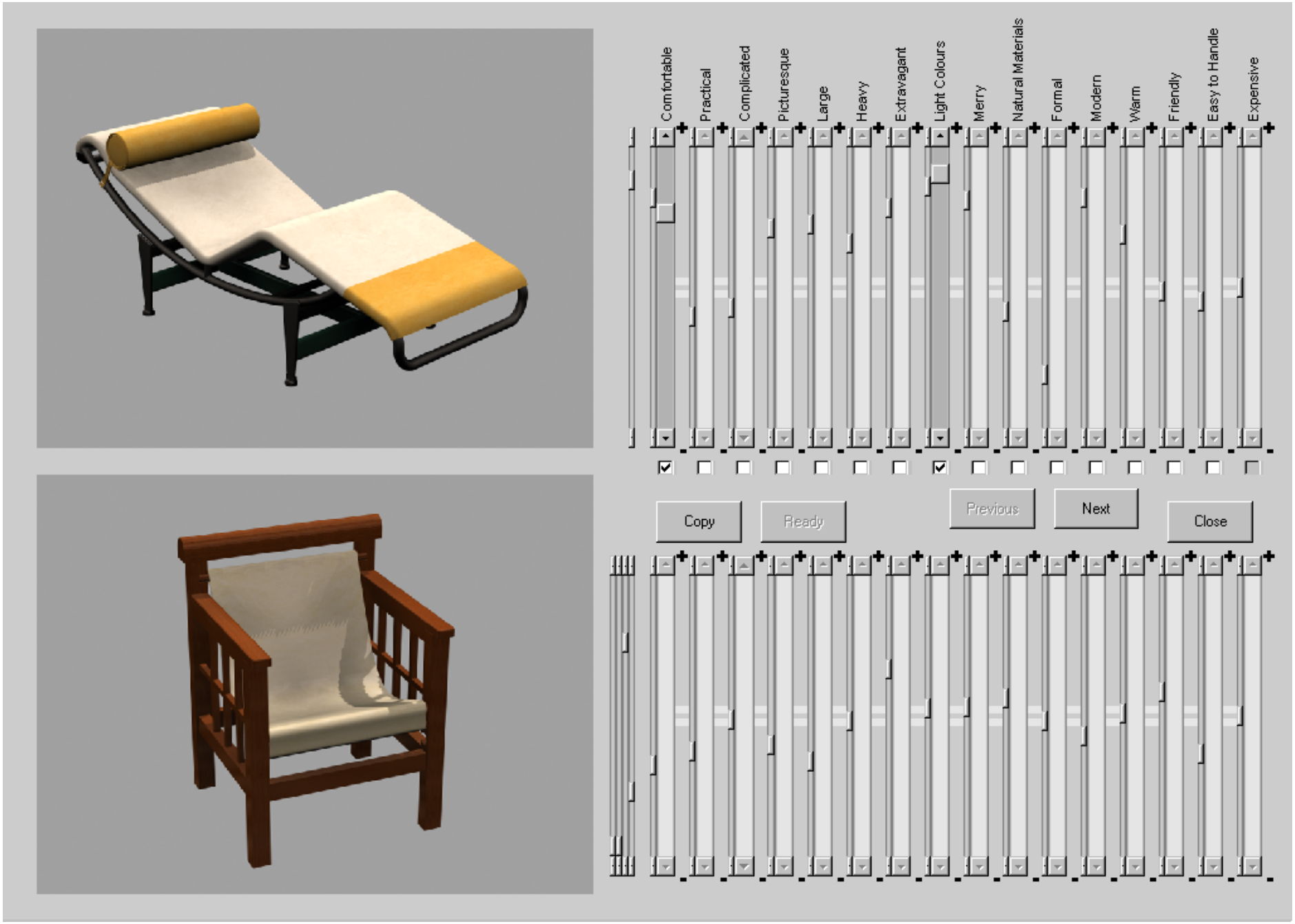
The user adaptive furniture selection

As an example of the proposed **Adaptive Emotional Model** structure, a furniture selection system was developed:

The goal of the selection system:

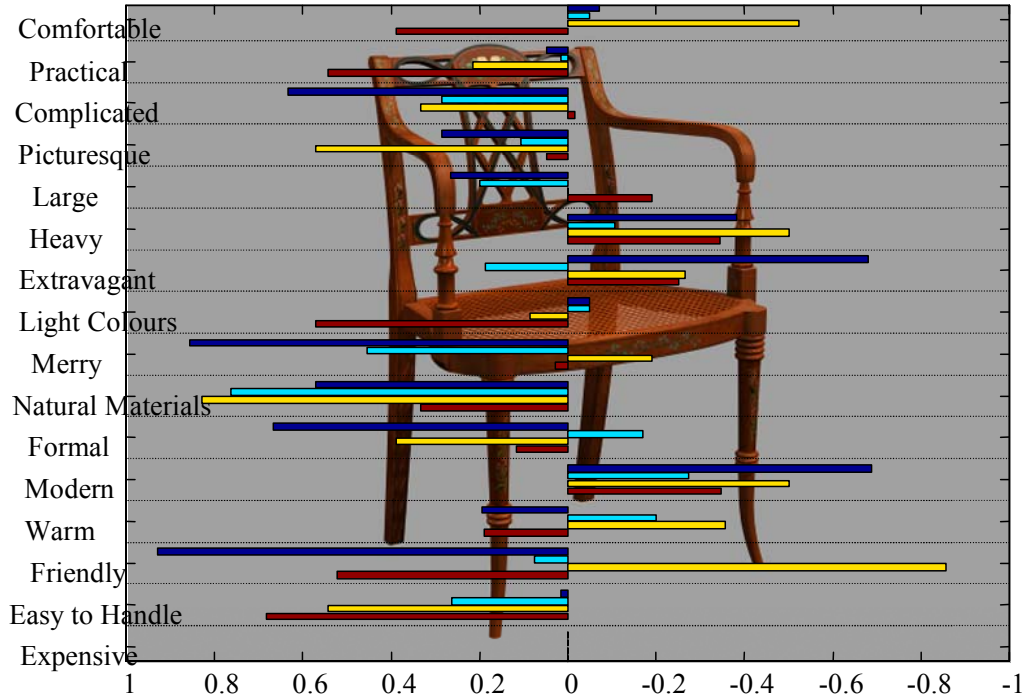
- To aid furniture (chair) selection by giving the chance to the user to **express his/her requirements through emotional levels**.
- The set of handled emotions is fixed to **16 emotional words related to chairs**.
- The user is **giving the requirements** by selecting some of the emotional words and **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**.)
- 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 emotional values** (16 in our case) related to the furniture on screen, fetched from the actual emotional model. **These values are appearing the same manner, on sliders** (side by the user sliders), 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**.
- 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 and adjusting some of the bottom sliders. Pressing the Ready button, the system recalculates the actual similarities.

Screenshot of the user adaptive furniture selection system



The emotional user models

- The existing emotional user models were generated **based on questionnaires**.
- The inquired persons had to make a **partial ordering of a set of pictures** of 43 different chairs.
- For each emotional 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 ~, ?, a little bit not ~, not ~, very not ~ - where ~ is the actual emotional attribute**. Than he/she was asked to **partially order the pictures of the same groups**. (Partially ordering was meant as ordering in the case of the pictures are distinguishable in respect to the emotional attribute, and signing equality, if they are indistinguishable.)
- 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 **Emotional descriptors**.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Picturesque
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Heavy
Extravagant
Light Colours
Merry
Natural Materials
Formal
Modern
Warm
Friendly
Easy to Handle
Expensive
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-0.8
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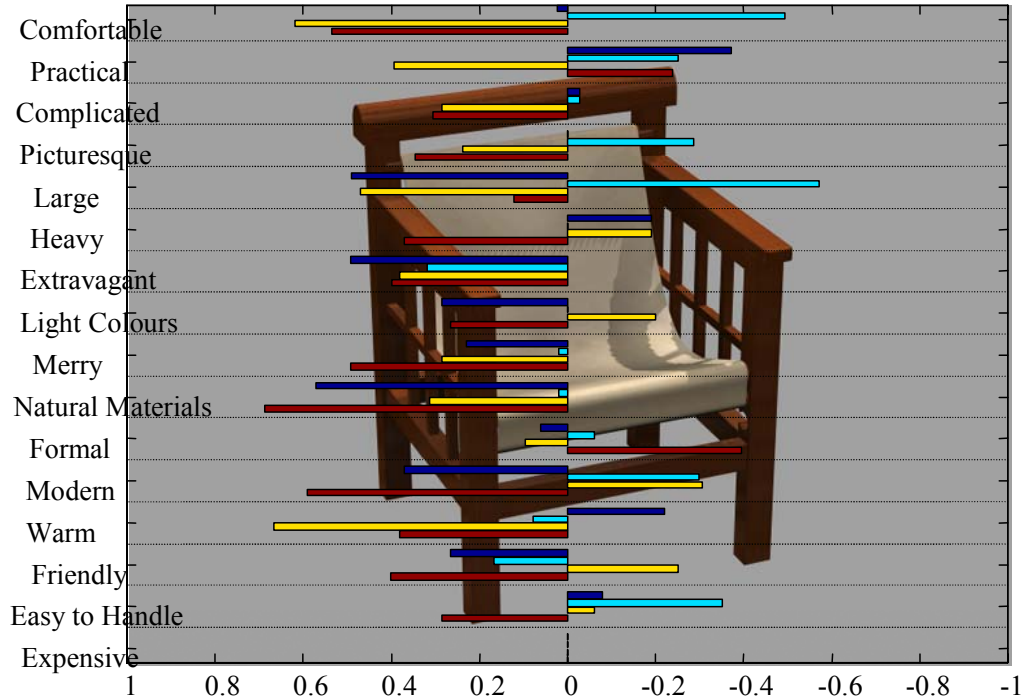
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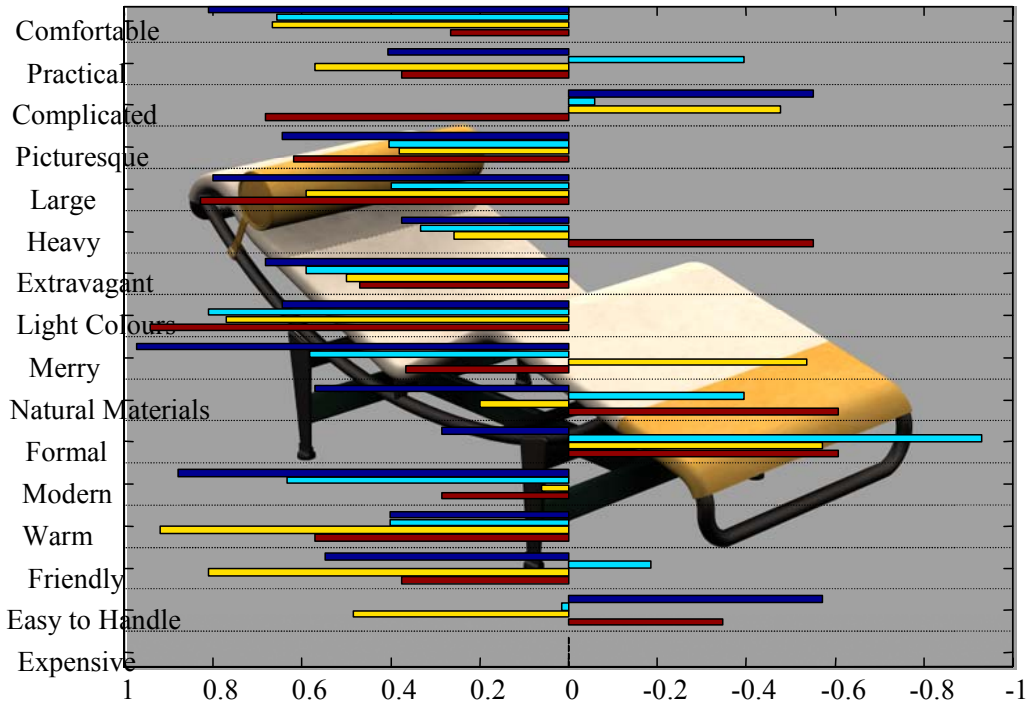
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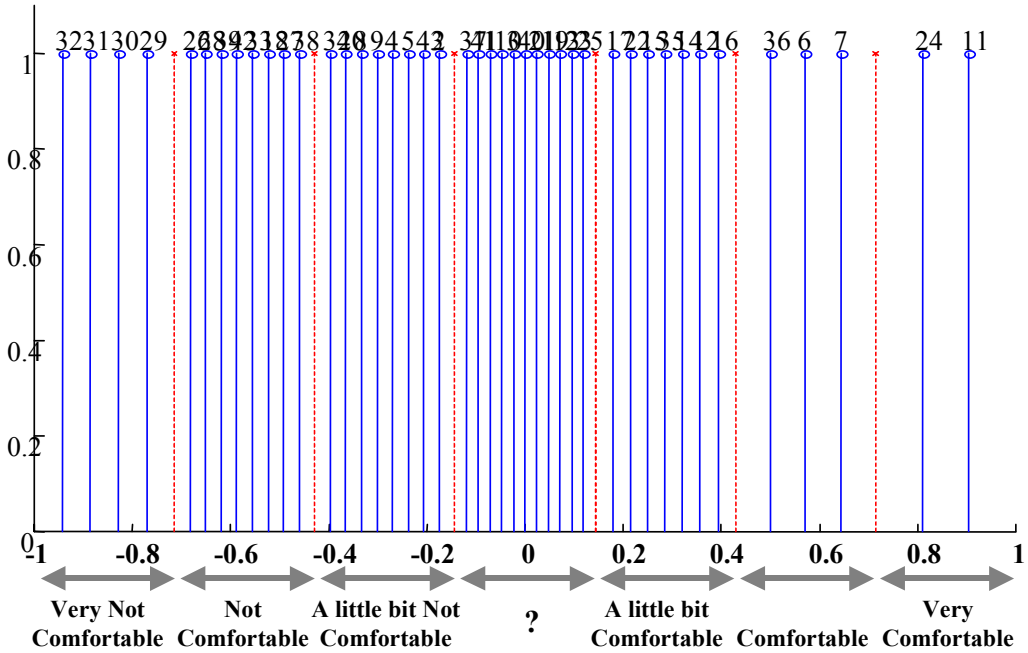
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-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Very Not Comfortable
Not Comfortable
A little bit Not Comfortable
?
A little bit Comfortable
Comfortable
Very Comfortable

Conclusions

Benefits:

– **Easy introduction.** (Implementing user adaptivity in an existing system)

– **Quick convergence** (online applications)
(User identification related to the existing models
instead of model identification)

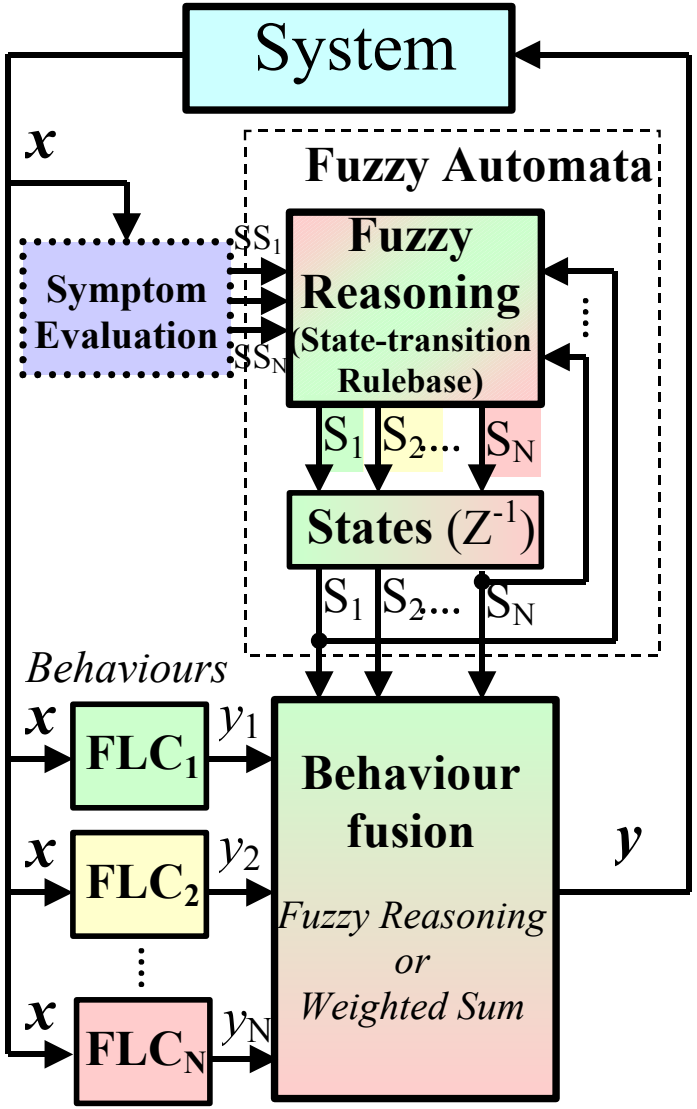
– **State identification**:
fuzzy automata (easy to modify, simply “readable”)

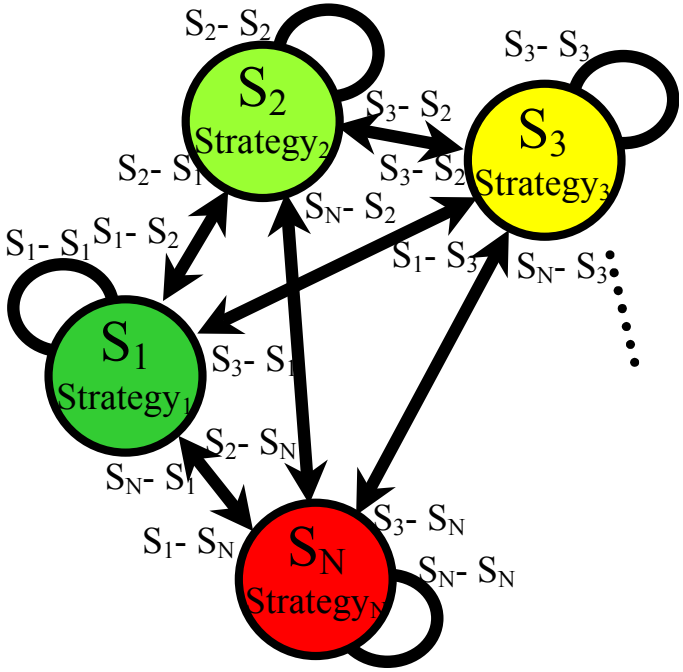
– **Model fusion**:
Fuzzy reasoning – flexible
Weighted sum – simple

Drawbacks:

– **Difficulties in collecting many models with high diversity.**

Adaptive Behaviour-based Structure





The basic structure of the state-transitions rulebase for the ith state S_i (R_{Ai}):

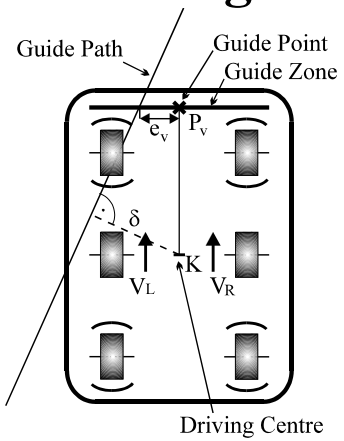
If	S_i=One	**And**	S_i-S_i=One	**Then**	S_i=One
If	S_i=One	**And**	S_i-S_k=One	**Then**	S_i=Zero
If	S_k=One	**And**	S_k-S_i=One	**Then**	S_i=One
If	S_k=One	**And**	S_k-S_i=Zero	**Then**	S_i=Zero

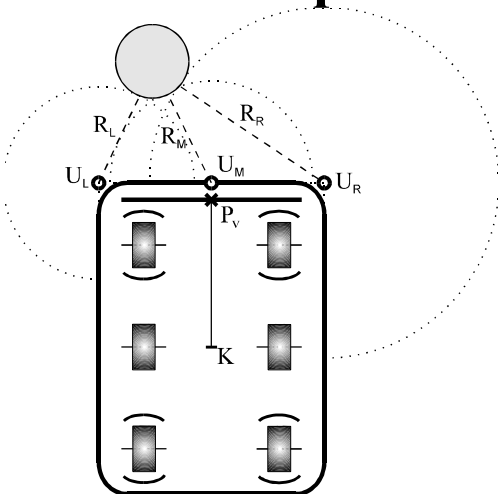
where S_i-S_j is the conclusion of the symptom evaluation about the state-transition from state i to j.

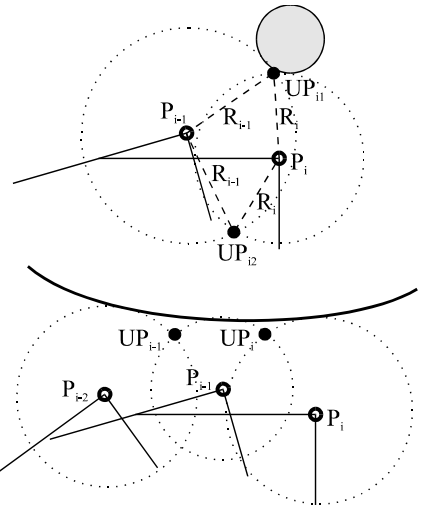
Strategy fusion rulebase:

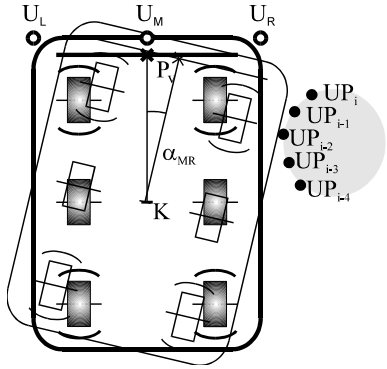
If	S_1=One	**And**	S_2=Zero	**And**	...	**And**	S_N=Zero	**Then**	y=y_1
If	S_1=Zero	**And**	S_2=One	**And**	...	**And**	S_N=Zero	**Then**	y=y_2
...									
If	S_1=Zero	**And**	S_2=Zero	**And**	...	**And**	S_N=One	**Then**	y=y_N

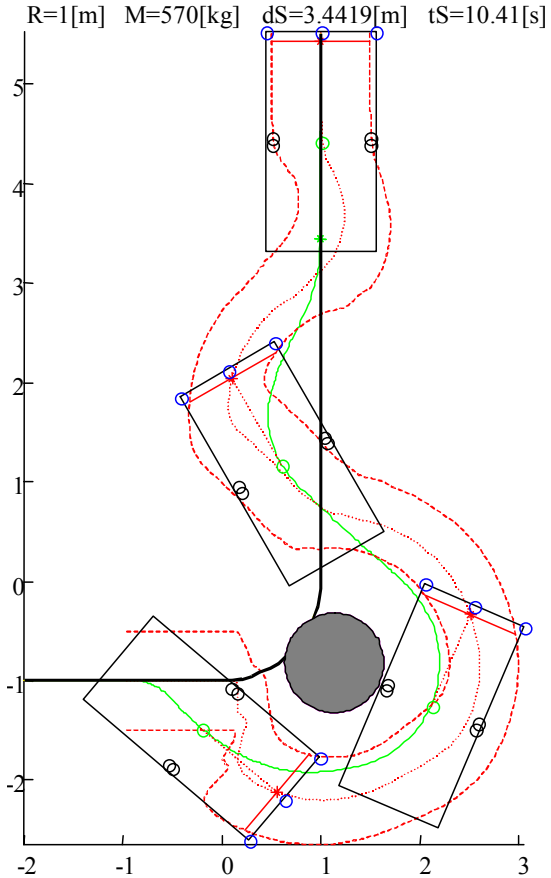
AGV navigation control example





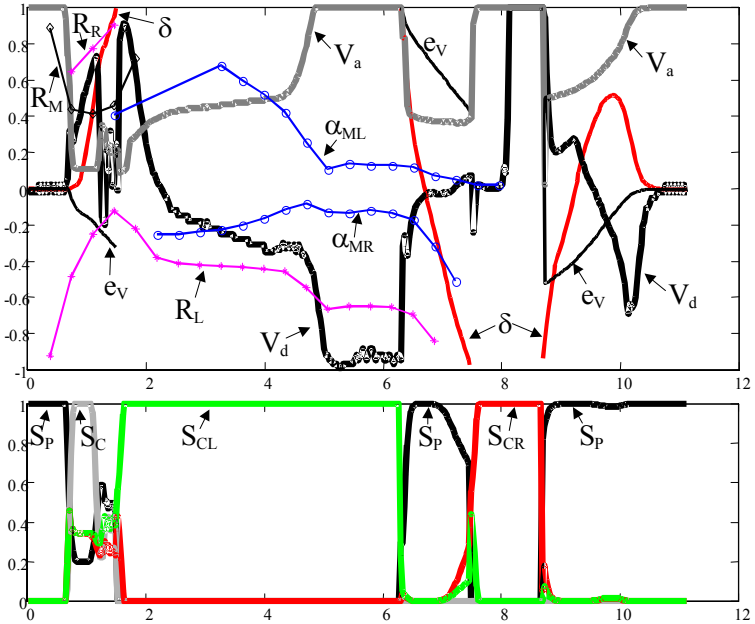




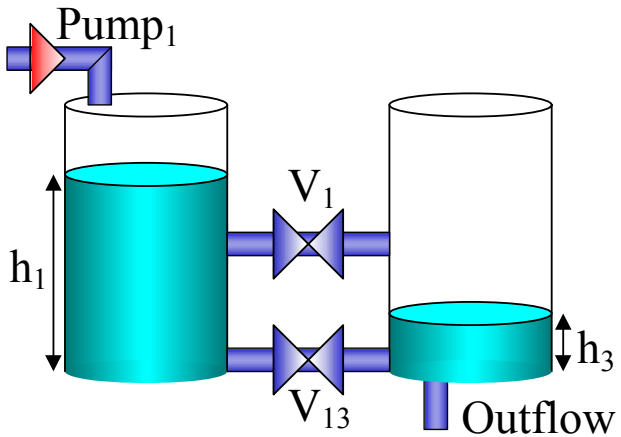


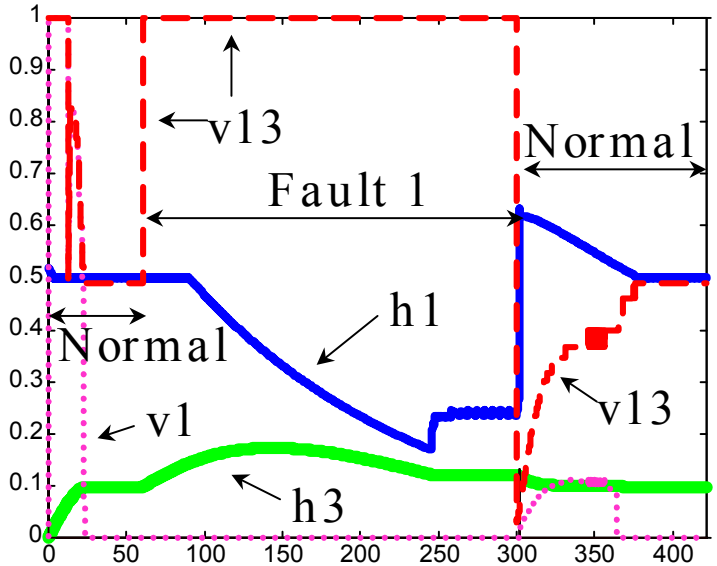
The known partial strategies:

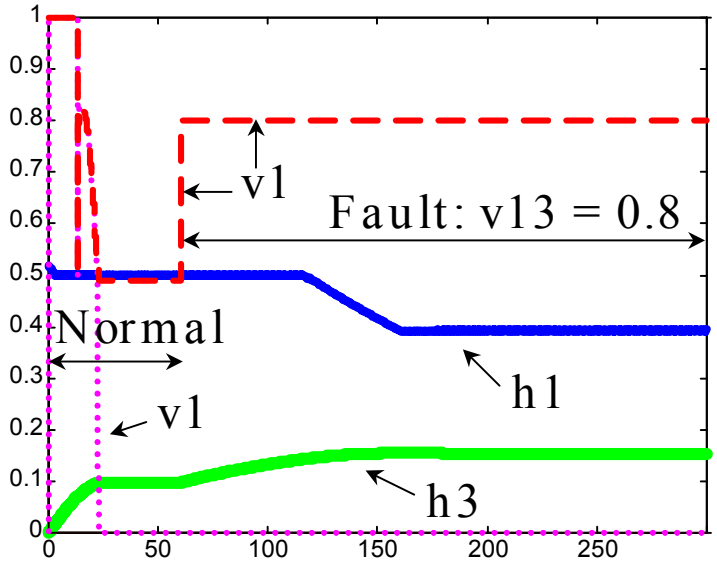
- Path tracking and restricted collision avoidance strategy
- The collision avoidance strategy
- The collision avoidance with left/right tendency strategy

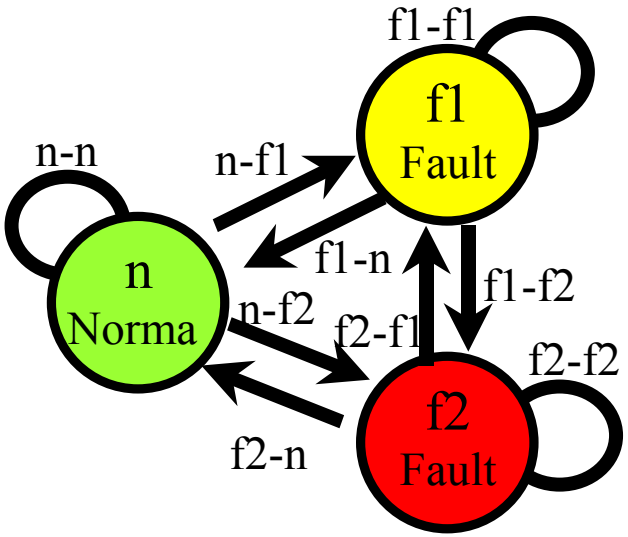


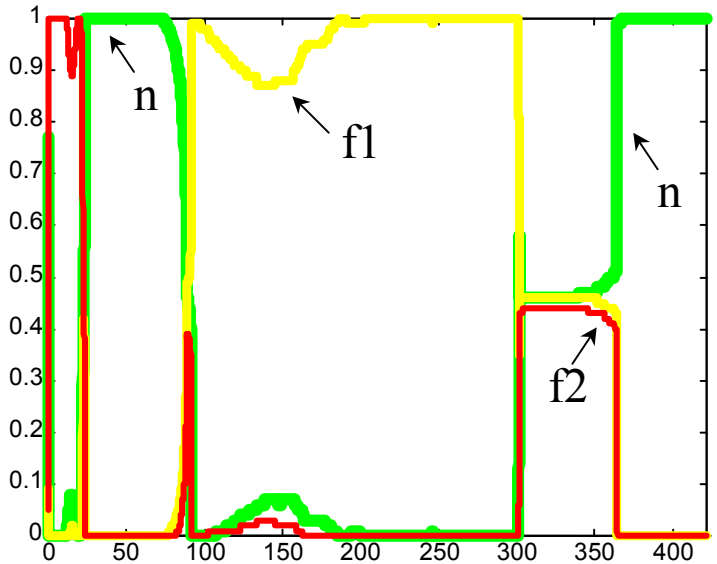
Fault tolerant control example

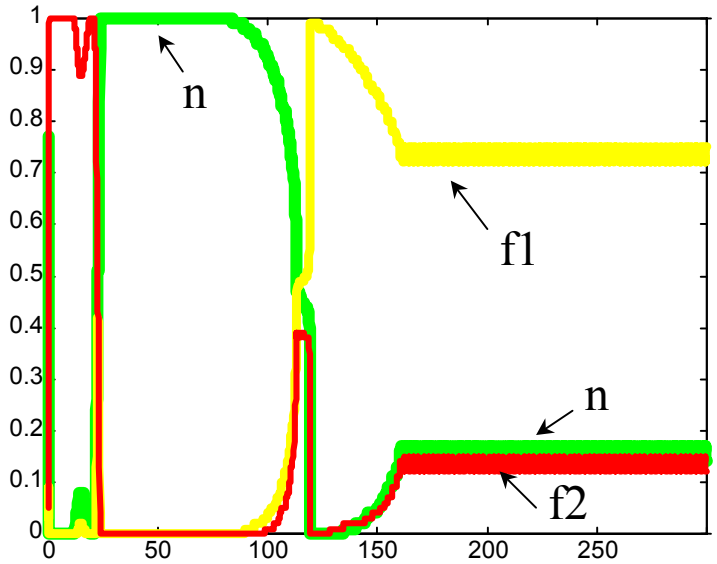












The structure was able to follow the studied operational modes (states) and state-transitions, even in some cases to approximate the unstudied situations, too.