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SYSTEM-THEORETIC UNDERSTANDING OF MMI - PART II: CONCEPTS FOR SUPERVISION

Dirk Söffker [*]

[*] *Dynamics and Control, University Duisburg-Essen, Germany*

Abstract: Core of this approach is the representation of human errors (given in terms of Dörner) within the SOM-formalization schemes. Using the SOM-technique introduced in part I, the human error classification and distinctions of Dörner are repeated in detail and firstly. Using the formal procedure it can be shown, that some distinctions (given with word-models originally) are not really sharp and need to be corrected. The combination of the logical and functional discretization of HMI using SOM-concept and the included formalizability of human errors (in terms of Dörner) allows the automated supervision of both players within the HMI context, the human and the machine.

Keywords: System-theory, Human-machine Interface, Human-error, Modeling, Supervisory Control, Man/machine Systems

1. INTRODUCTION

In a previous work (Soeffker, 2003) a system-theoretic modeling approach is introduced, dealing with a special situation-operator modeling kernel (calculus), called (SOM). This modeling approach combines classical ideas of the situation and event calculus, and leads to a uniform and homogenous modeling approach describing human learning, planning and acting, cf. part I.

Dörner and his group show in various publications (Dörner, 1989 f.e.) that human errors also within the HMI can be classified and therefore structured. Coming from psychology he used word models to describe and distinguish different (mainly 4) clusters of human errors and within more than 16 typical human errors. He assumes like others a classical action approach, which appears as a control loop between the environment (the machine) and the human operator (HO).

He distinguished human errors in

- goal elaboration,
- in decision processing,
- during the control of the action, and
- due to internal cognitive organisation problems

and demonstrated with various examples the idea and the usage areas of this ideas. The practical experience of the author with this detailed and nice distinctions is that it makes sense, to feedback this structured experiences about the human error classification to the operating humans itself.

Therefore the introduced SOM-approach and especially the graphical illustration technique can be easily used to skill HOs with this special view to HMI and human errors, so that interacting humans will become familiar with their own typical errors and can look to their own interaction and 'processing' behavior during their interaction. Therefore it is remarked that it is helpful to discretize the complex scenarios in a logical way by understanding the scenario / scenes and actions not by the individual understanding of the acting or supervising operator but using a logical filter, which discretizes the RW into a few easy to observe and monitor characteristicis.

This means that the real world (e.g. the technical system) will be logically discretized into parts of interest and of dynamical and functional relevance. Therefore the SOM-approach can be used. First practical results of skilling humans with explanations of human errors to optimize the internal reflecting and acting control loops show very good results. The idea now has to develop and to extend for automated supervision of Human and/or Machine.

Core of this approach will be the representation of human errors (given in terms of Dörner) within the SOM-formalization schemes. Using the SOM-technique introduced in part I, the human error classification and distinctions of Dörner are repeated in detail and firstly. Using the formal procedure it can be shown that some distinctions (given with word-models originally) are not really sharp and need to be corrected.

The combination of the logical and functional discretization of HMI using SOM-concept and the included formalizability of human errors (in terms of Dörner) allows the automated supervision of both players within the HMI context, the human and the machine.

2. HUMAN ERROR CLASSIFICATION OF DÖRNER

The classification of Dörner is from a system-theoretic point of view a descriptive one, no interpretation about the cause of human errors is made. The difficulty which has to solved is, that the psychologic interpretation about the logic of error (Dörner) has to be formalized. Goal of the formalization is to make the situations readable (for automata). If this is possible, the machine behavior as well as the human operator behavior and/or both can be supervised. The assumption therefore is the knowledge about the logic of action (coming from the task) has to be known by the supervision machine completely, or, the internal logic of connected actions has to be known (in the case of uncomplete knowledge) or unknown interaction has to be supervised.

2.1 Error: No part-goal elaboration

Based on the regular sequence of a planned interaction

- goal elaboration,
- action organisation, and
- action execution

the error 'no part-goal elaboration' assumes that the final goal of the sequence of action is central. The error denotes the not used / or not availabe property of the human operator to plan part-goals as a necessary mechanism to realize complex planning task by dividing into subtasks.

If humans are not able to divide goals into sub- or part-goals they are not able to 'see' the way how to solve complex tasks. The usual strategy to overcome these, is to build part-goals. (This mechanism is also introduced by the german philosopher Leibnitz introducing the term algorithm in the 18th-century).

Assuming the graphical SOM representation the errors can be easily expressed, cf. Fig. 1.

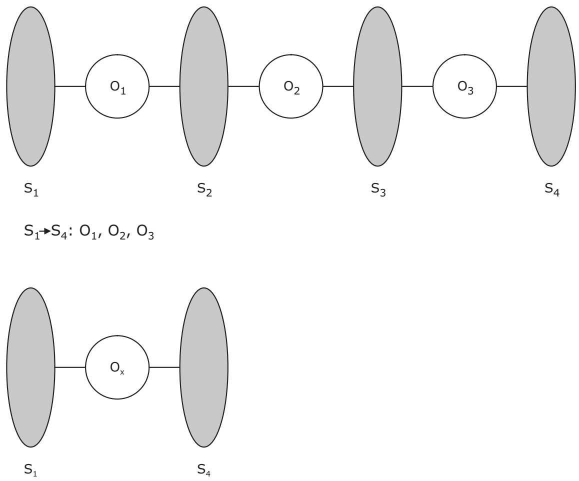

Fig. 1. Error: No part-goal elaboration

The desired final situation S_4 is tried to realized directly instead of using part-goals $S_{2,3}$. In the consequence, depending on the mental capabilities the necessary sequence of operators $O_{1,2,3}$ can not be defined easily due to the fact, the the step is tried to realize at once, instead of partly, which can be seen and understand using SOM-illustration easily.

2.2 Error: Establishment of fix goals / frictions

The human error 'Estblishment of fix goals includes, that goals after establishment will never be discussed by the human brain also in the case that this makes sense, especially by changes in between the planned sequences. It may happen that due to external changes the goal can never be reached by the developed strategy, so a new strategy is necessary.

Similar to this error is the error 'frictions', whereby this error includes, that the human operator is not considering changes induced by frictions, which also leads to non-reachability of the final goal.

The graphical illustration shows, that the basic problem is the wrong understanding of the human operator of O_1 concerning the function of O_1, so that the resulting situation S_2 can not be reached due to application of wrong operator. The application of the planned operator O_2 leads not to the desired final situation.

The planned sequence to reach to desired situation is based on the intermediate situation S_{2z}. The related necessary operator sequence is assumed as O_1, O_2. Unexpected in the reality the situation S_2 appears, whereby an additional characteristic D2 appears, which - in combination with the applied operator O_2 (or arbitrary others) does not lead to the desired situation. Holding to the desired situation S_{3z} or using of now non-useful operator O_2 lead to an error as illustrated in Fig. 2.

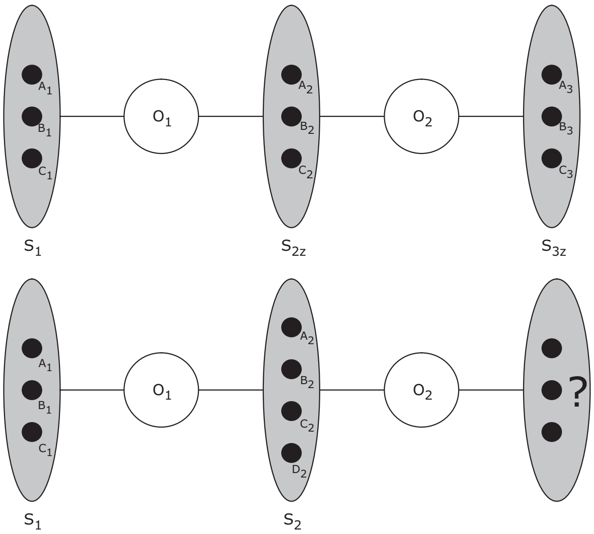

Fig. 2. Error: Establishment of fix goals

2.3 Error: Rigidity

Due to external effects the planned and desired situation S_2 is not reached, the different situation S_{2a} results. The human error 'rigidity' means that the unreflected use of O_2 will not lead to the desired goal due to the changed structural situation. The known and experienced operator O_2 will be realized (as in the previous sequences before), though the assumptions for application are not given.

Using the SOM-approach this can be easily graphically expressed.

2.4 Error: Magic hypothesis

Magic hypothesises appears in different ways in HMS. During the learning phase of the HO by

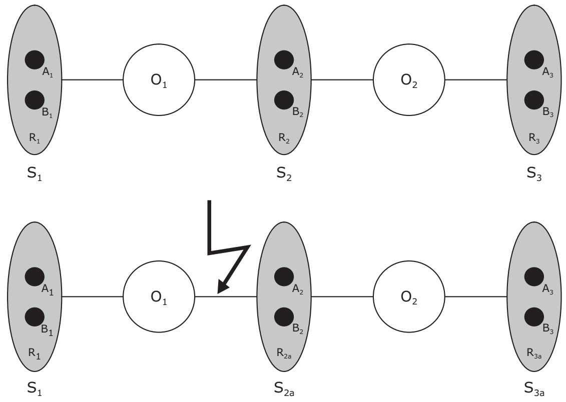

Fig. 3. Error: Rigidity

defining O_1 suddenly in the situation S_2 the characteristic D_2 appears randomly, and can not be explained by the effect of the operator. The consequence ist that now due to D_2 the operator O_1 is avoided, or is used with high preference instead of O_1 to realize $S_1 \rightarrow S_2$. Using the SOM-approach this can be easily graphically expressed. This effec of magic reasons can be explained by

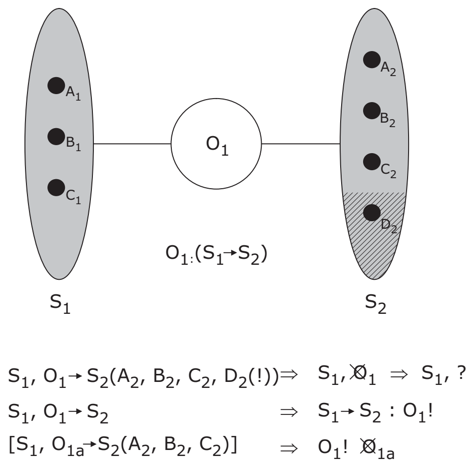

Fig. 4. Error: Magic hypothesis

previous, successful but not causal interactions.

2.5 Error: Central reduction

Central reduction is understand from Dörner und Schaub (Schaub, 1993) as the reduction of known and unknown variables (Schaub) or characteristics (Söffker) to only a few, usually not enough ones. In extremous situations sometimes everything is reduced to one variable: 'That's the weather, I knew it before'.

The human error 'Central reduction' contains the reduction of the desired situation
$S_2(R_2(A_2, B_2, C_2))$ to a few, structural similar but in the detail different goal situation $S_{2r}(R_{2r}(A_{2r}, B_{2r}))$. As a result the planning procedure is reduced to find the solution operator O_{1r} which is easier to realize and/or to execute

than the approbiate one. The supposition that the reason for the reduction of the goal situation may be the hope to find an easier to apply operator is not detailed here and also for the definition of the 'central error' term not necessary. Using the SOM-approach this can be easily graphically expressed.

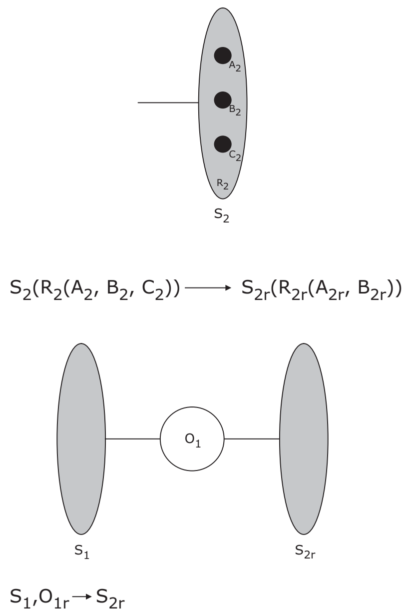

Fig. 5. Error: Central reduction

2.6 Error: Side- and Wideeffects

The individual incapacity to consider side- and/or wideeffects, this means to estimate the consequences of individual actions and to consider them in advance is one of the the typical human errors.

The human-error side- and wide-effects includes, that the choice of the operator O_1 leads beside the desired effects (f.e. A_2, B_2, C_2) in the desired situation as planned, to additional effects (like E_2) which are not planed and which are not desired. The definition of Dörner and Schaub does not consider the question if the new effects disturbs the desired situation or not, the important aspects comes from the unplanned and unexpected additional charakteristics. For Dörner and Schaub the important question is that this error is mainly caused by a wrong understanding of the choosen operator and/or a wrong understanding of the effects of the choosen operator. Using the SOM-approach this can be easily graphically expressed.

The distinction between side- and wideeffects can only be related to the time-related effects of the undesired effects. The immediate resulting effects can be classified as side-effects, the time-delayed but also directly caused effects can be understand

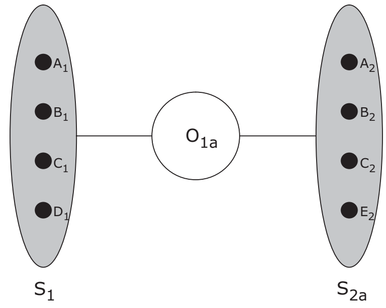

Fig. 6. Error: Side- and wideeffects

as wide-effects. So it is clear, that only the side-effect leads to undesired effects of the goal situation. This and the similarity between between fix goals and frictions as well as the similarity between fix goals and rigidity can not be seen from the original work of Dörner. Using the introduced SOM-approach avoiding any kind of interpretation it becomes clear, that some of the distinction are coming from interpretation.

3. CONCEPT OF AUTOMATED SUPERVISION OF HMI

Assuming

- common error mechanism for human operators in general,
- that the interaction mechanism as operators as well as
- the situation describing characters can be modeled and from a technical point of view be measured

it should be possible

- a) to examine the narrow sequences between situation and operator and following sequence,
- b) to follow the red line of clustered interaction sequences following a goal which is known before, and
- c) to search for internal connections and relate them to the introduced human error cluster.

By this way both sides of the HMI can be considered, examining the logic of the situation trajectory. Therefore the following modules have to been realized:

- Generation of situation vector: this module can be easily realized with existing signal- and/or model-analysis tools combining continous, discrete and logical informations in the way the independent system properties/states appear which can be understand as characteristics
- Description of operators for description of usual actions: this module can be easily realized with the knowledge of the operators and

system designers. The application of operators assumes necessary some characteristics and produces necessary changes. Monitoring this internal connections gives a lot of information.
- Analysis of sequences of operators etc: this module can be realized using existing neuro-/neurofuzzy approaches.
- Learning capabilities: this module represents the ability of the system to learn from the interaction, this task is up to now not solved but in progress.
- Cognitive capabilities: this module represents the ability of the system to organize his mental capabilities and his examining capabilities, this task is up to now not solved but in progress.

The mentioned last two modules realizes higher cognitive functions and are in progress realizing a high-level intelligent system. The previous mentioned modules are state of the art and has to be combined for application.

For offline-purposes the introduced strategy is already realized to analyse the HMI of

- human operators of an operating center of the german rail at Hagen Station, Germany, (1996/97),
- the analysis of the pilots error of Birgenair flight disaster (1997/98) and
- of political group processes (1999/00), and
- others.

In other projects of the author realized at the University of Wuppertal the mapping of verbal information from interviews and also the transcription of interaction information of computer gamers etc. to the SOM-approach has been successfully realized. This (german) spoken results will introduced and discussed at the presentation.

4. CONCLUSIONS

The introduced part II of the contribution deals with the formalization of the situation trajectory. It is shown that the human error classification of Dörner and his group (Schaub, 1993) can be interpreted graphically and is therefore easy to understand. The verbal human error model of Dörner can be expressed by the introduced SOM-approach. Due to the formal modeling procedure applicable to HMI, the approach can be used to examine also the interaction by an automatic algorithm. The paper deals with the idea of representing human errors in SOM-notification and introduces the conceptional ideas to implement algorithms for supervision of human and/or machine. The necessary modules are explained. The open task are mentioned.

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