Modeling the Human-Machine Interaction: Relations between Human Planning, Cognition, Mental Representation and Action using a Situation-Operator Scheme

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Abstract

Core of the work is an engineering oriented modeling approach of human cognition and of interaction using a specified situation-operator (SO) scheme. The strong relation between human interaction and mental models can be shown as well as the connection to related mental representations. The SO-scheme allows modeling of differend kinds of systems resp. modeling approaches, e.g. hybrid systems. The SO-scheme gives the framework modeling human activities and related mental activities including mental representations of models. The ability of the approach is demonstrated analyzing the crew-communication of the Birgenair aircraft accident.

Introduction

Dealing with phenomenological modeling to describe the Human-Machine interaction (HMI) some implicit assumptions has to be done, here given briefly:

- Something like the regular interaction is known, or can be reconstructed offline. This is due to the restricted goals of HMI-interaction scenes, as a consequence of the restricted technical possibilities.
- Assuming a reachable goal for the action, it can be also assumend that a limited number of a useful sequence of operations / actions exists, to reach the goal.
- To reach the goal it will be assumend that the series of operations is represented by a series of corresponding mental representations.
- The human consciousness is ordering those mental representations and controlling goals in a suitable manner. The concrete mechanism should be not of interest here. The resulting path is called *mental strategy* (Söffker 1997).

Modeling of reality using a situation-operator scheme

The model is developed in (Söffker 1999). Here some essentials are given very briefly. The task of the introduced situation-operator (SO) scheme is as follows:

- It works as a ordering scheme to discretize the actions of the 'world' and to define systems.
- It defines the elements of the human mental model, and
- it connects the 'world' with the human mental model.

The idea of the model *operator* is:

- Functional (causal) ordering of spatial, temporal and logical relations.
- Defining relations between output characteristics and connected explicit / implicit assumptions of systems.
- Building a framework combining different modeling approaches (as mental framework organizing the world's structure).

Operators can be build up by quantitative or qualitative mathematical equations, by algorithms or logical relations. In the real world different *operator's* are acting together. In the mental model world of humans these operators are used for copying the outside view of considered humans.

Within the projects of the SCE-group this theory is used modeling the HMI and defining mental models. Beside the HMI-examples the theory can be also used bringing together different mathematical modeling approaches like ODE's and discretized descriptions.

The details building operators (e.g. for hybrid systems) are omitted in favour of the HMI-orientation.

Fig. 1. gives a arbitrary part of changes of the real world by a sequence of actions and statements.

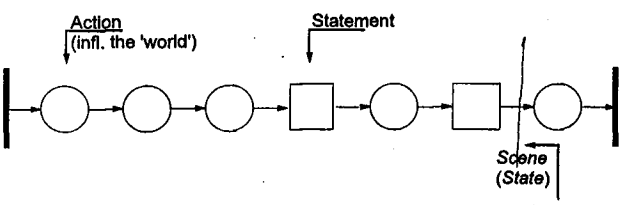


Fig. 1: Situation-*Operator* concept (Söffker 1997)

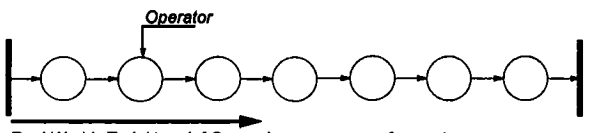
The fixed situation is defined as *scene*. The *scene* is connected with surrounding items. The sequence of *operators* (here as actions (changes) and statements) is defined as a *trajectory*. So the considered part of the 'world' can be understand as a discrete-event system of the linear sequence of actions or statements modeled driven by related operators.

Here the *operator* is used as simple input-output function changing the *scene*.

Assume *learning* as the assignment of the differences between *scenes* to the supposed causal reason called the function of an *operator*. In this way *operators* (as actions/statements in the 'world') can be both: ordering element of the outerside-world and mental element of the human cognition. It is clear, that the learning possibilities depend on the complete actual individual human mental model and on the observation possibilities. *Learning* can be active (the individual human is connected with *scenes* itself and dealing with *operators* or passive (the individual human is not connected with the considered *scenes* itself). For the reconstruction of mental elements (as the learning-procedure of the reconstructor) everything is an *operator*. Everything outside the reconstructor contains something of the structure of the considered *scene*: indirect (so it can be concluded to the mechanism of the *operator*) or direct (because the *operator* contains/carries a (true) statement about the world. Reconstructing the HMI means that parts of the mental model of the considered interacting human (H) are understand as *operators* of the outerside 'world' of the reconstructor, so every action and every statement of (H) are understand as *operators* to the reconstructor used to conclude to the mental elements of the mental model of (H).

Reconstruction of the mental model of human operators

Understanding the mental models of human operators as the analogon of *operators* by the *learning* procedure; actions and statements of human operators can be used for the procedure as (unknown) *operators*.



Real World: *Trajektory* (of *Scenes*) as sequence of *operators*
Human Planning: *Mental Strategy* using *Operators*
Human *Learning*: Definition of *Operator* by the Changing of *Scenes* (active)
or: *Operator* contains Statements of the *Structure of the Scenes*

Fig. 2: *Operators* for reconstruction purposes as well as for learning the mental elements of the considered individuum from the view of the reconstructor

The main assumption for the reconstruction process is, that elements of the *structure of the scenes* are objective known. These assumptions restricts the reconstruction process itself to formalized 'mini-worlds' like the Human-Maschine Interaction, as a decoupled area. Without knowledge about the regular trajectory it is not possible to conclude to unknown elements.

Example: Examination of the Birgenair crew communication

Using the background of the regular interaction trajectory the differences to the real interaction are given using the CVR-transkript (NTSB 1996).

The examined key sentences (S) and key actions (A) of the pilot are:

1-S *My airspeed indicator is not working.*
(on the runway before 80 knots check)
2-S *It began to operate.*
(after take-off, before flaps procedure)
3-A Flaps procedures
4-A *Center autopilot on please.*
5-S Copilot: ... *200 only is mine and decreasing sir.*
6-S *Both* (Rem: indicators) *of them are wrong.*

Lets consider the logical core of the *operators* (S), the connection between the actual mental model related to the actions (A) and the logic of the *scenes* resulting in the developing *trajectory*. Using the illustration of fig. 3 as a necessary background to understand the logical structure of the *scene* and the problem of the pilot to understand the *scene*.

The main question is: Is the pilot able to learn about the different function of his airspeed indicator using the available informations and his knowledge during the exciting trajectory? Is he able to differentiate

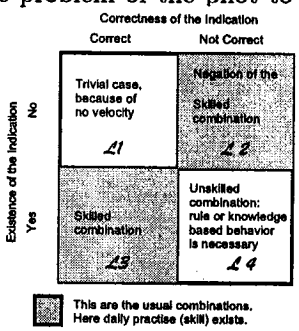


Fig. 3: Differentiation between Existence of Indication and Correctness of the Values

between the existence and the correctness of the indication? The 4 different logical possibilities are expressed by L1 to L4, cf. fig. 3.

The development between discrete event system development, actions and statements of the pilot(s) resulting in a assignment between the continous system development, the discrete events and the logical behavior (Fig. 3) can be illustrated in detail and is given at the symposium.

As a result it can be stated, that it is difficult to conclude from L3 to L4 without additional informations. It can be assumend, that the pilot was not able to conclude the difference between L3 und L4, and with the *operator* 3-A (where the exspected speed is the same as the indicated one) he has no reason to accept L4.

References

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