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COOPERATIVE EVALUATION FEEDBACK: AN INFORMATION TECHNOLOGY ARCHITECTURE, SUPPORTING THE SUSTAINABILITY

Béla CSUKÁS
Kaposvár University, Faculty of Economic Sciences, Department of Information Technology,
H-7400 Kaposvár, Guba S. u. 40

ABSTRACT

Consciously developed cooperative system architectures might have an important role in the technological and economical foundation of sustainable development. Contrary to the usual present understanding, the notion of cooperation is significantly more sophisticated than the mutual goodwill or the consideration of the mutual interests. According to our recently developed approach, in the cooperative control the joint sub-systems control themselves and each other in a way that makes the realization of the favourable states also for the functionally linked parts possible. Similarly, in the cooperative design the connected parts have to be configured in a way that makes the advantageous evaluation possible also for their functionally linked neighbours. This framework, combined with the previously developed generic process simulator and multi-objective genetic program, offers a new methodology for various practical problem and cannot be easily solved with a conventional approach. The computer assisted organization of cooperative evaluation feedback will be illustrated by examples.

Keywords: process architectures, evaluation feedback, cooperative processes, cooperative control and design

INTRODUCTION

Engineer designed and controlled cooperative systems seem to play an essential role in the solution of the present and forthcoming problems of solving the human made economical and ecological crisis.

Cooperative systems and cooperative processes do not have a generally accepted definition in the international scientific community. Cooperation literally means "working together". This is the root of all modern uses of the term. It denotes some kind of activity conducted between two or more people, usually for a common goal. The notion of cooperation appeared in the early works of many systems' scientists (*von Bertalanffy,* 1969; *Axelrod,* 1984), however, the ideas moved from natural sciences and engineering toward social sciences (e.g. *Argyle,* 1991).

Regarding the Hungarian scholars, it is to be noted that in many works of Tibor Vámos the cooperative systems were emphasized as one of the concurrent organizational principles of the hierarchical systems (e.g. *Vámos,* 1983).

Nowadays for the Google query of "Define: cooperation" we find many scores with not too much relation to natural and engineering sciences. The queries of

"Define: cooperative system(s)" or "Define: cooperative process(es)" give only three particular answers.

Considering the present state, many research teams, working in various research fields use different, sometimes very specific, sometimes quite coherent interpretations and applications of the "cooperative principle". Recently the cooperative ideas have intimately been combined with the agent based approach (e.g. *Saricicek,* 2007).

In Hungary the Laboratory of Engineering and Management Intelligence at Computer and Automation Research Institute of Hungarian Academy of Sciences works intensively in this field (e.g. *Monostori,* 2005).

MATERIALS AND METHODS

In our approach cooperative processes are defined by special, mutual evaluation feedback loops between the "collaborating" part-processes.

According to our understanding (*Csukás*, 2000) the generic structure of the process models can be characterized by a special net structure of the "passive" state elements and of the "active" elementary transitions. The skeleton of the structure is a bi-layered "bis-digraph" consisting of two kinds of nodes and of two kinds of edges, determining multiple feedback loops. The various discrete or continuous, quantitative or qualitative, as well as deterministic or stochastic functionalities are associated with the nodes as brief program codes, while the edges represent the communicating channels from the state to the transitions and *vice versa.*

In the balance models the state elements are different measures (additive quantities), while the transitions determine the transportations and transformations of these measures. The measures can be defined as a special subset of Halmos measures (*Halmos*, 1984). The conservational models represent a special case of balance measures, which can be calculated from the model specific constant measures, according to the stoichiometry of the model specific conservation law.

In the informational models the state elements are optional simple or complex signs, while the transitions determine the optional rules overwriting these signs.

The common structure of the balance and informational processes led to a new interpretation of the informational processes. Accordingly, a given part of the conservational process behaves as an informational process with respect to its complementary part if this special part consumes and produces significantly fewer conservational measures than the complementary process, while, along the feedback influence loops and transferring influence routes the informational process exerts more influence on the complement, than the completing part on it. The informational process can be a special part of the self-determined natural processes (e.g. neural system, enzyme regulation), or it can be a supplied part of the non-self-determined artificial processes (e.g. control systems). The essential feature of the informational process is that it

- transports negligible amount of conservational measures with the complementing part and with the environment,
- while it has a greater influence on the operation of the complementing part than *vice versa.*

It is not necessary to describe the conservational processes for this special subsystem if the above criteria are fulfilled. Instead, we can read, calculate and overwrite the appropriate signs simply. Accordingly, we neglect the conservational process carrying these signs and deal only with the informational process carried by the vehicle conservation process.

Based on the previously enumerated results we began to elaborate a general framework for various kinds of the structure based sensitivity analysis (observability and controllability in control, identifiability and modifiability in identification, evaluability and configurability in design, etc.).

Evaluation can be considered as a special kind of secondary information that orders the alternative solutions (variants) according to one (or more) points of view.

In problem solving, the generic simulator can be combined with a new multi-criteria discrete/continuous genetic algorithm (*Csukás*, 1998). The genetic algorithm prepares an initial population. Next the kernel generates and simulates the variants, one after the other, followed by the evaluation of the prescribed objectives. With the knowledge of these evaluations, the genetic algorithm proposes a new population to be studied, while the new variants will be tendentiously better. Because of the very limited communication between the genetic algorithm and the simulator, the method can be executed in macrogranular parallel architectures (cluster, GRID) effectively.

RESULTS AND DISCUSSION

In our approach the *cooperative systems are characterized by the mutual evaluation feedback between the components.*

Accordingly the essence of the cooperative control is that the functionally connected components control themselves and each other in a way which makes the realization of the favourable state possible also for the functionally connected neighbours.

Similarly, the essence of the cooperative synthesis and design is that the functionally connected parts have to be configured and evaluated in a way which makes the evolution of the favourable evaluation possible also for the functionally linked neighbours.

For the better understanding of our concepts about the evaluation feedback based cooperative processes, we start from the set of schemes in *Figure 1.*

The notations are the followings:

$\check{S}$ the discrete and continuous possibilities,
$\hat{s}$ the alternative solutions (variants),
$\mathbf{v}$ the (inner evaluation based) selectors from the possibility space,
$\mathbf{E}$ the outer evaluation of the alternative solutions (variants),
α,β identifiers of the multiple objectives.

Using these notations the hierarchical architecture is visualized in *Figure 2*, where the lower left indexes correspond to the levels.

Figure 1

Simple, two objective and consensus objective evaluations

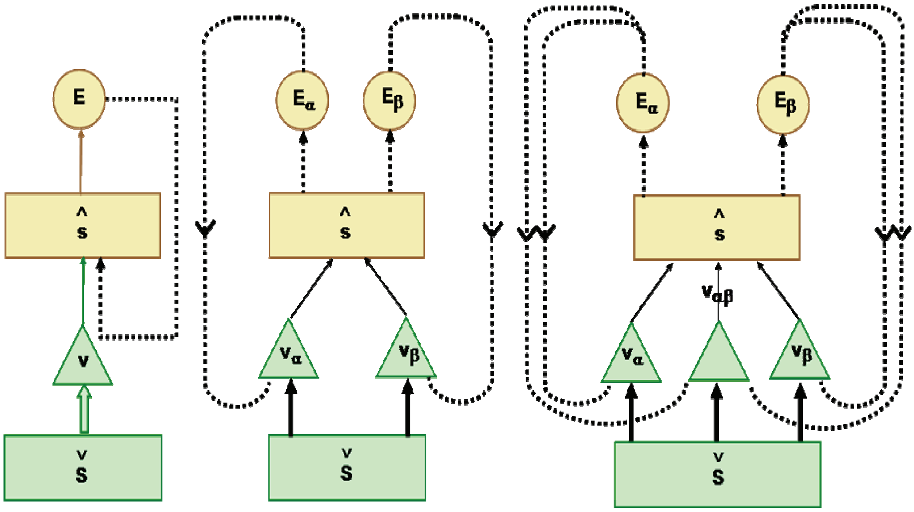
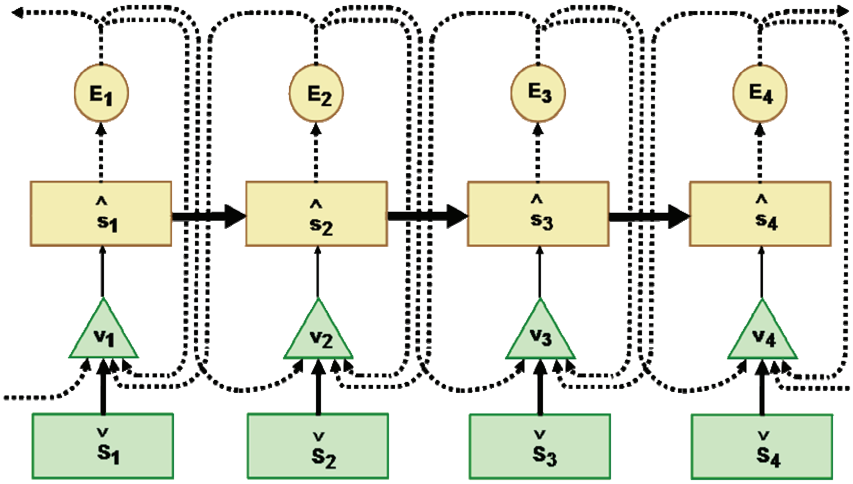


Figure 2

General scheme of the hierarchical evaluation



On the contrary, the essential structure of the cooperative evaluation can be seen in *Figure 3*. As a special case a "cooperative pair" can be seen in *Figure 4*.

Biological processes of each level can be characterized by the dominance of the neighbourhood connections. Especially the interactions, accompanied by greater mass and energy transport (i.e. the conservational processes) are functioning according to the neighbourhood.

Figure 3

General scheme of the hierarchical evaluation

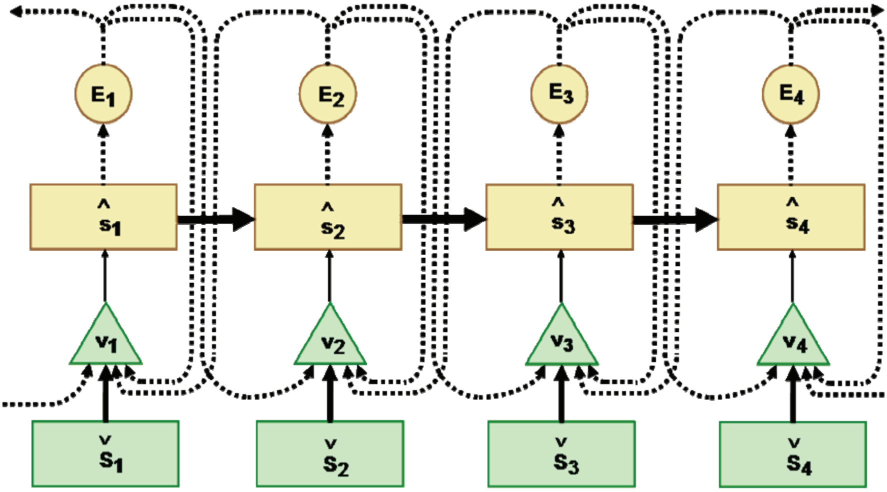
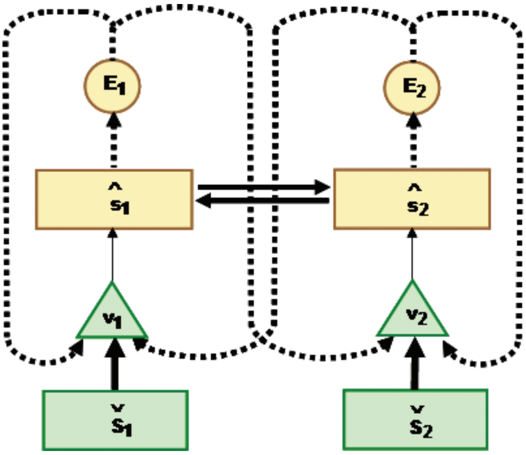


Figure 4

The scheme of a "cooperative pair" (e.g. cooperative identification and control based on the same model)



One of the most important features of the biological subsystems is the tendency to keep a compromise between the autonomy and the environmental interactions. Biological systems tend to decrease the disturbances and try to stabilize the advantageous circumstances for the essential functionalities of a given sub-process, on the one hand. Simultaneously, the functioning of the sub-systems needs energy and/or mass input and/or output between the autonomous parts and the environment, on the other hand. This contradiction is the driving force of the spontaneous development of the more or less isolated parts (units, compartments, etc.). The isolation can be realized in explicit by physically existing selective walls (membranes), or in implicit by the regulation scheme of a given subnet.

The good performance of the functionally connected sub-processes depends on each other, mutually. If one of the subsystems fails, then it might be harmful for the connected parts, and the dissipation of the malfunctions might destroy the whole system. To avoid this case, there are cooperative feedback loops between the functionally connected neighbouring sub-processes.

As another example considers the suboptimal model based design and control of large scale technological systems with local evaluations based on uncertain cost functions. In the applied cooperative architecture the functionally connected parts of the process are forced to develop such suboptimal states that allow to develope the suboptimal configuration also for their neighbours. This method might tend to develop first steps toward "natural economics". It is worth mentioning that in this field the models of the cellular metabolism and of the large logistical systems can learn from each other effectively.

Accordingly, a typical example is the simulation based planning and scheduling of supply→production→demand chains. In this case we prepare the model also for the detailed dynamic simulation of the measures of demand and costs coming from the sales, as well as from the purchases and processing. We can investigate the possibility of the cooperative local decisions about the alternative and/or concurrent elementary processes based on the costs and on the measures of demand, associated with the respective storage volumes. The possibility space of the model is determined by the alternative purchases and sales, as well as by the concurrent production steps. According to the previous experiences, the method tends to select the locally advantageous suboptimal solutions for each subsystem. Simultaneously a natural cooperativity evolves in the system, because the same storage volumes are connected with various elementary processes that results in the overlapping of the neighbouring local sub-goals.

Cooperative mutual feedback model of identification and control might also be an important feature in the understanding of the top-down structures behind the intelligent behaviour.

CONCLUSIONS

A new class of cooperative processes has been defined, characterized by the mutual evaluation feedback between the functionally linked part-processes. Accordingly, in the cooperative control the joint sub-systems control themselves and each other in a way that makes the realization of the favourable states possible also for the functionally linked parts. Similarly, in the cooperative design the connected parts have to be configured in a way that makes the advantageous evaluation possible also for their functionally linked neighbours.

This framework, combined with the previously developed generic process simulator and multi-objective genetic program, finds a new methodology for various practical problems, and cannot be solved easily with a conventional approach, e.g.:

- hybrid model based design and control of large scale, long term complex recycle processes (e.g. between agriculture and sustainable industry);
- detailed model based design and control of supply chains (outlining a bottom-up, local decision based economy).

The conscious and sophisticated studies on cooperative processes from engineering viewpoint, must contribute to the real world process based foundations of the forthcoming economical paradigm.

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Corresponding author:

Béla CSUKÁS
Kaposvár University, Faculty of Economic Sciences,
Department of Information Technology
H-7400 Kaposvár, Guba S. u. 40.
Tel.: +36-82-505-950
e-mail: csukas.bela@ke.hu