Multi-Parametric Control of Complex Object in the Program System For Physician's Decision Support

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Abstract[1]

The task of multi-parametric control with mutual interference of actions is described. These control actions are of special interest when issued for the object with behavior that is hard or even impossible to formalize. An approach to the "treatment" formalization is developed. This approach considers "medical curing" as a control action that is described using the principles of theory of control, theory of problem solving, data mining and case-based reasoning. The concept of object control in the circumstances of multiple external actions with complex and nonformalizable influence on the human being organism is practically implemented. It is used in the "Doctor's Partner" program system. The system was designed to help the physician who is trying to diagnose and choose the appropriate treatment.

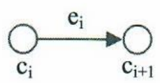
1. Introduction

"Doctor's Partner" is a program system which is designed by the Institute for system programming of Russian Academy of Sciences and Moscow Regional Clinical and Research Institute. The design and development of the system are supported by Russian Fund for Basic Research within projects No 09-07-00191-a and No 09-01-00351-a. The system is implemented on the basis of control theory, data mining methods and case-based reasoning [1]. The basic idea is to think about curing and treatment as of the process of controlling the object. Practically useful system [2] is the realization of a conceptual control system that is able to function under multiple external actions that influence on different organism state parameters. The main task of the system is to make it possible to sufficiently consider multi-parametric effects that can be seen as a behavior of a complex controlling object – human being organism for which it is really impossible to get mathematically adequate behavior model.

Building a control system based on several different theories is not the same as just to unite several different simpler systems that are solving the common problem together. The external factors may appear to be contradictory, for example, the need of immunosuppression transplantology in adverse epidemiologic situation when the risk of either a viral infection or a tuberculosis development is extremely high. The problems of control system project that arise from the complexity of external actions and control object states formalization are also in effect.

2. Case driven control

Any step of object control [3] may be represented as a scheme:



where c_i is an object state before action, e_i is a control action, and c_{i+1} is an object state after action. This triplet we shall call "a case". In medicine an action is an element of treatment which consists of remedies, procedures, operative interventions and so on.

The cases that are following each other in time, are forming the so called "control action chain". The nodes of the chain represent object states, while the arcs represent

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control actions. The overall set of object states and actions comprises the "case base".

One of the simplest control strategies is to react upon the input events while the latter are generating. This strategy assumes that the action is selected basing on the state analysis, is called "closed" control, or "feedback" control. "Adaptive" control differs from the closed one by the presence of object model, which is used to analyze the possible action effects. Making this analysis in fact means forming a prognosis. The correct reaction is only possible when the formal object description (mathematical model), which shows object behavior in the functioning environment, is accessible. For human being organism that is a very complex object, it does not look possible to get the exact behavior model. Instead, one can access a priori information about object states, control actions and actions effects (results). The structured scheme of adaptive control process, where mathematical model is substituted by the collected case base, may be seen in fig.1.

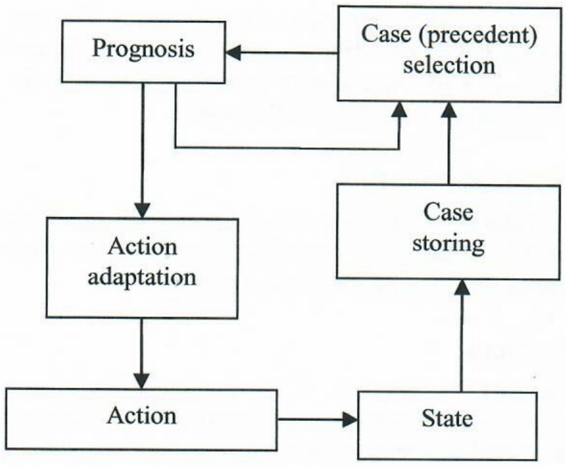

Fig. 1. Case-based adaptive control

The case-based reasoning method main problem is the selection of the most suitable cases. To solve this problem is to find a method of comparing cases to decide which of them is most similar to the current case [4, 5]. Sometimes it is possible to form general patterns – state classes, which are constructing based on a priori information about the application (e. g. with the help of data mining methods). If this happens then any control action can be treated as a map of one class onto the other (or maybe onto itself).

Comparing the "before action" object state with the "after action" object state is doing in the object features space. A point in this space that corresponds to the object is being looked for in the projection of classes onto the space of object features. The gaps in object description may result in ambiguity of classes' positions. This means that the objects may be positioned within the region of classes' intersection. One of these classes will be the source class. During the next step the action should be selected. It will be looked for among the actions which were already been chosen for previously investigated states. The "after action" states will be compared to each other within the same feature space. The cases that achieve the needed class are considered as more preferable (fig. 2).

2. Control chains

Object action can be represented as a set of constituents each referred to a particular object feature, or a group of such features (state parameters). These features are used to manage and control the object. Significant part of control techniques, and particularly controlling the physical objects, assume that actions for every separate feature do not depend on each other. Taking into account this assumption makes it more convenient to consider the object control process as a set of several nonintersecting chains (fig. 3).

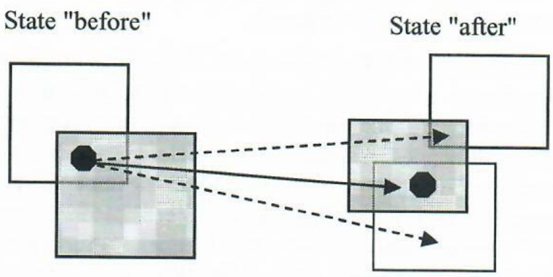

Fig. 2. Cases selection

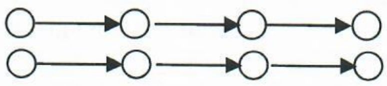

Fig. 3. Independent control chains

Introducing of several chains is only an abstraction. In fact there exists the only one multi-parametric chain of states and actions each refers to the same object. Still such a separation of a complex chain is convenient and justifiable: in medicine a physician having a particular professional specialization is trying to control a set of features which are the most typical for his set of diseases. But the abstraction of independence cannot be used always. On human being organism, which has complex internal relations and significant compensating facilities, the action forcing one feature may become apparent through others. Having such a situation one has to compensate the effect of the first action and generate additional actions dealing with alternative groups of features. Sometimes the influence of such actions may be mutually dependent or even mutually exclusive. The following is the example from medical practice. With intensive therapy of serious pathology in the conditions of water-electrolytic imbalance a patient may occur in danger of liquid redundancy. In this case a physician is controlling the values of (high) arterial blood pressure, congestive plethora in lungs, existence of peripheral and cavernous edema and other aftereffects, concerned with the liquid redundancy. To improve the patient state different methods of dehydrogenation are used. These methods may result in lowing blood pressure, lowing kidney perfusion, edema occurrence, lowing protein level in blood. In turn these effects may be compensated by excluding of natrium and potassium, by introducing of albumen and so on. Evidently the action on one group of features has an effect on others. Keeping the acceptable situation is a very difficult task.

One can imagine different types of mutual influence of actions. Let us consider an object state with two groups of features with separate control abilities in diagram form. Let c_{11} be an initial object state for the first group, while c_{21} will be an initial state for the alternative group. Let the action e_1 change the object state to c_{12}, this action will also change the alternate feature to c_{22}. We can either treat this action as an additional action that changes the state from c_{21} to c_{22} (fig. 4a), or as a diversity action from c_{11} to c_{22} (fig. 4b). And finally, there may exist mutual impacts on both chains (fig. 4c).

The existence of bifurcation point shows that a control action forces us to evaluate the object state according to the additional group of features. Even more complex mutual influences developing on different chains may occur in practice (fig. 5). In general the case will be represented as a one moment set of object "before" states, set of actions, plus set of object states "after" plural action on all the groups of features. With several control action chains the task of action selection assumes simultaneous solving of several subtasks, each similar to the one shown on fig. 2. An adequate prognosis of action results, especially of multifactor action results, can be achieved only on the basis of sufficient number of cases, which cover all possible mutual influences. The case base may contain or may have a lack of information about some group of features, or some action effects on different features. The lack of information about action influence on the object state doesn't always mean the absence of such an influence. This only means that adequate information is still need be collected in future.

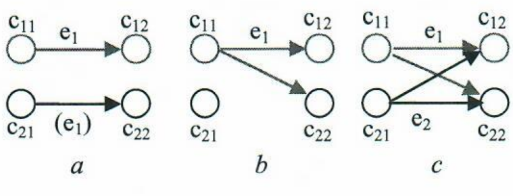

Fig. 4. Mutual influence of different actions onto one object

If there is no adequate case in the base, one needs to follow random selection algorithms while choosing the action. One can also choose an action without making a prognosis. In any case in order to get adequate result it is necessary to look for optimum action value ranges. The factor action is a very complicated task, which is not enough formalized and strongly depends on application

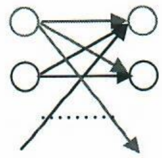

Fig. 5. Different action chains interlacing

area. That's why on this stage even in medicine it is intended for a person who is an expert in his profession.

3. Conclusions

- The principles of building the adaptive control system for complex objects that is designed on case-based reasoning with data mining techniques are designed.
- The principles designed are used in the program system "Doctor's Partner", implemented for physician's decision support in diagnostics and treatment choosing.
- The work on the system is still in progress. The new possibilities of dealing with complex mutual influences of simultaneous control actions onto the object are introducing into the system.

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