Category-theoretic Methods for Studying Causality in Distributed Systems

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The report describes the category-theoretic approach to the study of causality in discrete distributed systems. The trend of widespread use of distributed computing, observed in recent years, is a technological answer to the practical achievement of the upper bound of processor performance on the one side and the development of communication tools on the other. In addition, there is a tendency to integrate cybernetic and physical systems, which has been accelerated in the context of developing Internet-of-Things.

The analysis of the problem allows us to state that the problems associated with controlling parallel, distributed and concurrent computations turned out to be on the leading edge of Computer Science and Information Technology. In the focus of studying this problem area, the problem of modelling causality in distributed systems holds a central position, in particular, modelling based on the concept of logical time. There are two approaches to model logical time, namely, the event-based approach and the state-based approach. Unfortunately, the set-theoretic language does not give a natural description of the relationship between these approaches. Our research focuses on the use of the language of category theory, which is adequate for constructing models, is based on events and is based on states.

There are a lot of studies deal with controlling discrete event dynamic systems, which use the category-theoretic languages. These studies use the category-theoretic notion “adjunction” to describe the interrelation between event-based and state-based models of the systems.

Our main results are as follows

1. the category of clock structures has been defined; this category is used to define event-based models of logical time;
2. the subcategory of linear clock structures in the category of clock structures has been defined; this category is used to define physical models of logical time;
3. the category of schedules has been defined; this category is a bridge between event-based and state-based modelling approaches;
4. equivalence between the categories of linear clock structures and schedules has been proven.