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Formal Treatment of Knowledge in Water Science by Means of Event Bush

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Hydroinformatics has developed a kit of numerical models based on various mathematical formalisms. However, real-world environments are unavoidably more diverse and complicated than model assumptions, and there is an unavoidable conceptual gap between a model and a practical task, which is getting wider as widens the latter.

Bridging this gap (that is, making lucky choice of parameters and mathematical formalisms best fitting the nature) is traditionally considered as an issue of scientists' experience and intuition. However, with growing complexity of geoscientific tasks and the need for communication of knowledge to non-scientific community, universal approaches like event/probability trees and, more recently, Bayesian Belief Networks (BBNs) entered the geoscience. They allow to project any existing model (qualitative as well as quantitative), dataset, and expert guess against the contents of particular domain of knowledge (evolution of a river valley, pollution of a basin, regime of mountainous glaciers, etc.). The contents is represented herewith as a network of nodes denoting key parameters of the environment, and edges meaning the relations between the parameters. Any relevant information can be related to the corresponding node(s).

Along with obvious benefits, such approach has its innate shortcomings. Treating in similar (say, conditional-probabilistic) way the results of computation from models based on different formal approaches (e.g., deterministic, probabilistic, and fuzzy) increases the uncertainty of end result. Yet more serious difficulty is the high degree of subjectivity in the representation of contents. Indeed, one phenomenon can be de-

scribed by infinitely many BBNs that differ either in the number of nodes, or definitions of states of similar nodes, or graph structure, and so forth. This brings us back to the intuition as the only judge in choosing between alternative BBNs (or choosing of "optimal" nodes, their states and edges while building a new BBN).

The solution is seen in development of a method complementary to BBN for processing the semantics of domain of geoscientific (including hydrological) knowledge, which would (i) decrease the subjectivity by putting the representation of contents on as much formal ground as possible and (ii) determine the involvement of different mathematical formalisms based on the representation of the contents.

The method of event bush, based on simple and therefore likely universal, contents-independent classification of statements in the domain of knowledge, has been developed to meet this claim. Statements form its nodes and describe the key parameters of the environment. We report the fundamentals of event bush, including the types of relations between the statements, the approach to formulation of basic statements and the procedure of generation of subsequent ones. The polytree graphic form of event bush looks intuitively clear and thus may serve as a basis for reconciling competing standpoints in professional discussion and transferring scientific knowledge to interested non-professionals and students. Being essentially deterministic, the event bush, nevertheless, allows the values of statistical or logical/subjective probability be assigned to its nodes, the probability distribution being determined by the relations between the nodes. Given this, the event (now probability) bush can be automatically converted into a BBN. It can be also extended to account for natural variability of objects. This is done by partial or thorough fuzzification, parallel to, and independent of, assigning conditional probability values to its nodes. In this case the nodes of the resulting BBN would have more states and probability distributions of the nodes will be corrected correspondingly. Event bush can also be extended to have time intervals and spatial coordinates assigned to the nodes, which makes event bush useful for different kinds of temporal modeling and, theoretically, compatible with geoinformation systems technology. Dimensions of future research also include combination of event bush with different tools of computational intelligence and further formalization of contents by means of first-order predicate logic.

Yet the first attempts of application of event bush have shown its pertinence to a wide range of domains of knowledge, from volcanology to hydrology. We present an event bush for sedimentation and natural recycling of iron and manganese ore in transitional freshwater/marine environments by the example of Gulf of Finland, Baltic Sea. The roles of hydrologic regime and sediment transport in evolution of ore deposits are considered, existing hydrologic, sedimentologic, and geochemical models, including the controversial ones, are put in a complex conceptual framework formulated in trans-

parent, laconic and easily traceable terms. This framework, with further development, is expected to become the basis for an intellectual geoinformation system uniting existing numerical models and describing the phenomenon of Fe-Mg subaqueous ore deposit formation in a transitional shallow-water environment.