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Kinematic Structural Modelling in Bayesian Networks

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We commonly capture our knowledge about the spatial distribution of distinct geological lithologies in the form of 3-D geological models. Several methods exist to create these models, each with its own strengths and limitations. We present here an approach to combine the functionalities of two modeling approaches – implicit interpolation and kinematic modelling methods – into one framework, while explicitly considering parameter uncertainties and thus model uncertainty.

In recent work, we proposed an approach to implement implicit modelling algorithms into Bayesian networks. This was done to address the issues of input data uncertainty and integration of geological information from varying sources in the form of geological likelihood functions. However, one general shortcoming of implicit methods is that they usually do not take any physical constraints into consideration, which can result in unrealistic model outcomes and artifacts.

On the other hand, kinematic structural modelling intends to reconstruct the history of a geological system based on physically driven kinematic events. This type of modelling incorporates simplified, physical laws into the model, at the cost of a substantial increment of usable uncertain parameters. In the work presented here, we show an integration of these two different modelling methodologies, taking advantage of the strengths of both of them.

First, we treat the two types of models separately, capturing the information contained in the kinematic models and their specific parameters in the form of likelihood functions, in order to use them in the implicit modelling scheme. We then go further and combine the two modelling approaches into one single Bayesian network. This enables the direct flow of information between the parameters of the kinematic modelling step and the implicit modelling step and links the exclusive input data and likelihoods of the two different modelling algorithms into one probabilistic inference framework. In addition, we use the capabilities of Noddy to analyze the topology of structural models to demonstrate how topological information, such as the connectivity of two layers across an unconformity, can be used as a likelihood function.

In an application to a synthetic case study, we show that our approach leads to a successful combination of the two different modelling concepts. Specifically, we show that we derive ensemble realizations of implicit models that now incorporate the knowledge of the kinematic aspects, representing an important step forward in the integration of knowledge and a corresponding estimation of uncertainties in structural geological models.