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The Bayesian fusion paradigm for integrating geophysical models: theoretical framework and application to sedimentary basin exploration

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Cost-effective exploration of the subsurface needs the integration of different information over the target geo-resource. Single models of complementary physical properties (e.g. seismic wave velocity and resistivity) have often been integrated to obtain a multi-physics model of the shallow crust. However, the single models to be integrated (a) come out from geo-observables with different depth-resolutions and collected with different survey geometries; and (b) are reconstructed adopting different strategies for solving different geophysical inverse problems. This makes the integration process a non-trivial problem. Moreover, a simplified, qualitative integration of geophysical models prevents the correct quantification of uncertainties in the physical parameters of the "integrated" model.

In this study, we report a new strategy for probabilistic integration of geophysical models, called "Bayesian fusion" algorithm. Localised point-investigations of a rock volume produces single pieces of information, in the form of 1D/2D/3D models, geometries (e.g. structural features) or punctual measurements (e.g. from boreholes). In the Bayesian fusion approach, these single pieces of information are probabilistically re-appraised within the entire volume of the subsurface. In the new technique, previous information on each physical property or structure are casted in the form of known Posterior Probability Distribution (PPD) of the parameter over the study volume. Such PPDs are integrated in a single 2D/3D structure (i.e. all the physical parameters display the same geometrical distribution within the volume), where value of the physical properties and geometry of the structures are fully consistent with the assumed PPDs. The theoretical framework of the new algorithm and its core functionality are presented in detail for a simple 2D integration of 1D elastic models, together with a 2D resistivity model and an interpreted reflector from an active seismic line. The algorithm is validated using both synthetic data and field measurements collected across the Dublin sedimentary basin.