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Uncertainty Representation in Hydrographic Surveys and Products

Brian Calder*

Although many advances in estimation, use and maintenance of high resolution bathymetric uncertainty for hydrographic data have been made in the recent past, there has not been the same emphasis on representation of uncertainty at the user level (i.e., in final products), and the use of uncertainty at the planning, monitoring and qualification of hydrographic surveys has been limited. This paper attempts to address these issues by proposing a model of a generalised uncertainty expressed as a mathematical risk that could be used for both purposes.

Current representations of uncertainty for the user often express the Hydrographic Office's knowledge of their surveys. Source Diagrams, for example, are typically qualified only by date and a general description of survey technology: unless the user has a very detailed knowledge of survey systems, introduction date and survey methods, their ability to form a reliable estimate of the state of knowledge of the seafloor anywhere on the chart is necessarily limited. Other technologies such as Reliability Diagrams and CATZOC zones in ENCs provide more, or at least differently encoded data (given they are used), but still typically describe the measurements made, rather than a consistent description of the state of knowledge about the seafloor in the chart's area. This does not effectively answer the user's basic question about the uncertainty in the chart: what is my effective risk in assuming that the chart faithfully represents *all* of the relevant data where I want to be?

As an alternative, this paper proposes a probabilistic model of uncertainty that attempts to describe the user's risk directly, instead of trying to summarize the survey effort with a vertical bathymetric uncertainty. The core of the technique is a simple model of the underkeel clearance (UKC) experienced by the hypothetical user as a function of space, time and the user's likely dynamics. Augmented by probabilistic assessment of the likelihood of anything not on the chart being able to affect the UKC, an estimate of the probability density function of the UKC is computed. This is then teamed with a loss function that describes the likely cost associated with the user having any particular UKC. Computed from such factors as required safety margin, seafloor composition, ship's cargo, etc., the loss function summarizes the consequenceis of decisions - in this case, the choice of UKC at any particular area. (More complex decision theoretic considerations are clearly possible where the losses associated with more discrete decisions could be examined to assess mean loss, or best decision paths.) The combination of probability density function and loss function provides an assessment of mathematical risk, from which the differential risk (i.e., risk per unit time or area) and total risk (or expected loss) can be computed. Crucially, the differential risk per unit area is a scalar value that can be readily represented in chart form, and directly answers the important question of the risk associated with traveling through a particular area; the line integral of differential risk along the user's trajectory answers questions about total risk.

A number of extensions to this general framework are obvious. For example, very similar arguments can be used to develop a risk profile for either prospective or on-going survey operations. Decisions of whether to survey, and to which standard, could be rationalized by a risk model that balances the cost of conducting the survey against the potential loss associated with an incident in the area if the survey is not conducted, levened by the probability of detecting new objects in the area, potential for change since the last survey, type of traffic, etc. Completeness of survey, and prioritization of effort during the survey, could be couched in terms of the residual risk left in the area and where the risk was concentrated, respectively.

In this paper, the general framework for the risk analysis formulation of uncertainty is presented, and illustrated using both simulated data and examples from the Shallow Survey dataset in Portsmouth, NH. We examine in particular the problems of sparse data and the role of geological context in the risk assessment, and the outstanding difficulties in fleshing out the framework for particular cases.

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