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COMMUNICATING UNCERTAINTY INFORMATION ACROSS CONCEPTUAL BOUNDARIES

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ABSTRACT

Broadly speaking, information about data collection and modeling risks are locked with information providers rather than shared with downstream information consumers. Information consumers downstream often ingest products automatically, and without protocols to inject uncertainty, the ensemble modeling products so common in ensemble modeling cannot accurately account for the input modeling uncertainty inherent to those products. Incorporating practitioner-driven rules and protocols to transmit tiered uncertainty information between information product producers and consumers and establish use cases in the naval environment will advance the needs of environmental, social, and economic actors in the ensemble modeling chain and allow for improved error transmission throughout the decision making enterprise. Challenges and opportunities to the practitioner across the environmental and geospatial landscape are considered along with lessons from simulation modeling and other domains.

1 CRITICAL NEED IN ENVIRONMENTAL AND SUSTATINABILITY POLICY

Environmental and sustainability policy is driven by the need to effectively convey uncertainty information. As noted by (Adams 2006), sustainability is ultimately a problem that must transcend boundaries between the environmental, social, and economic. In addressing the work by (Edwards 2010), (Allen 2010) noted that "We should aim to convert unknown unknowns into known unknowns, not pretend we can eliminate them." To this end, a key driver in communicating environmental data products is the effective communication of uncertainty as a first-order information product. When there is a failure of the environmental to properly convey uncertainty to the social and economic domains, there is great risk for loss of trust (Anon. 2010). At the same time, increasing domain specificity has increased the amount of uncertainty experienced by elements of these groups (Gross 2010). Furthermore, the importance of understanding climate change has been identified as a key driver for national security policy with the United States Navy (Committee on National Security Implications of Climate Change for U.S. Naval Forces; National Research Council 2011). Numerous authors within climate change research have identified the communication of uncertainty as a challenge, including (Bitz 2008),

These challenges are heightened because the economic, social, and environmental domains do not always share a common understanding of uncertainty. Economic measures for uncertainty often focus on risk. For example, a seminal effort by (Knight 1921) first identified the 'the ones we don't know', the type of risk that would be immortalized as the 'unknown unknowns' of Secretary of Defense Donald Rumsfeld (U.S. Department of Defense 2002). Trivially, any effort to communicate uncertainty cannot communicate these risks, but can only move our downstream target audience to include the risks communicated by upstream uncertainty. Nobel prize winning approaches to the applications of the decisions between uncertain alternatives includes (Tversky and Kahneman 1992). (Hirshleifer 1979) conducts an excellent survey on some of the great thinking about information uncertainty in the economics domain, including discussion about modern portfolio theory from (Markowitz 1959). The visceral nature of uncertainty as applied to information asymmetry that reducing your automobile trade-in are discussed in (Akerlof 1970).

Social models for uncertainty certainly appear to lag the efforts in the environment and economic domains. Examples thought to be well solved in the environmental domain such as near term weather forecast still show cracks in conveying uncertainty. A recent effort by (Morss, Demuth, and Lazo 2008) demonstrated the different ways that the general public interprets the implicit and explicit uncertainty in weather forecasts. The book by (Patterson 2003) discussed the challenges faced by the public in digesting uncertainty in public policy.

2 GEOSPATIAL DOMAIN EFFORTS

The Joint Committee for Guides in Metrology (JCGM) publishes standards and shares these standards with partners such as ISO, IUPAC, ILAC, BIPM, IEC, IFCC, OIML, IUPAP. Two major approaches include the GUM (Guide to the Expression of uncertainty in measurement) (BIPM et al 2010) and the associated document on propagation of distributions using a Monte Carlo method (BIPM et al 2008). Numerous specific papers can be found to highlight the use of these standards in practice (Lira and Grientschnig 2010), (Bich, Cox, and Harris 2006) or even teaching the communication of uncertainty. However, it is difficult to say whether these documents offer a conclusive solution to the challenges of communicating uncertainty.

An exciting effort is underway under the Seventh Framework Programme that addresses the need to communicate uncertainty by establishing a markup language standard called UncertML (Williams et al. 2009) for the Open Geospatial Consortium (OGC), the leading standards organization for geospatial services. This is part of a broader UncertWeb project which is tasked with making "the uncertainty enabled model web a reality" (UncertWeb 2011). This includes efforts to produce APIs to support information and service models and demonstrations of UncertWeb concepts.

Other various efforts in communicating best practices in uncertainty as applied to climate modeling and decision-making have also been documented, including (Morgan 2009), Efforts to manage uncertainty across the IPCC are documented in (Swart et al. 2008) and the broader philosophical challenges to a shared uncertainty lexicon are discussed in (Manning 2003). (DG Robinson 1998) performs an extensive study of uncertainty analysis techniques from the period 1956-1985 applicable to complex systems. (Regan, Colyvan, and Burgman 2002) construct an ecologically focused taxonomy of uncertainty in conservation biology. An effort by (Hunter and Goodchild 1993) identified the key issues of definition, communication, and management of error in spatial databases. (Goodchild 1998) takes a critical look at the lack of uncertainty information in GIS systems. Land cover change modeling in Geographical Information Systems (GIS) based on historical map data is presented in presented in (Leyk, Boesch, and Weibel 2005). Further efforts in the geospatial domain have included (Thomson et al. 2005), (Worboys 1998), (AM MacEachren et al. 2005), (Couclelis 2003), and (Torres et al. 2004).

3 CHALLENGE ACROSS NUMEROUS DOMAINS

Transmitting uncertainty information across organizational boundaries exists as a challenge in numerous contexts. In the domains of intelligence and policy analysis, IARPA (Intelligence Advanced Research Projects Activity) has targeted the program ACE (Aggregative Contingent Estimation) to solve questions relating to the elicitation, aggregation, and communication of expert opinion used to forecast global events. Here the approach is to apply prediction markets to collectively assess event uncertainty, as promoted in (Arrow et al. 2008) but with innovative weighting schemes based on forecaster traits as found in (Dani et al. 2006), (Ranjan and Gneiting 2010), and (Cooke, ElSaadany, and Huang 2008). Studies such as (Tetlock 2005) establish the effectiveness of prediction markets as well as unweighted opinion pools.

Failures in communicating model uncertainty have been linked to the 2008 United States financial crisis (Salmon 2009). Salmon argues that the inability of end users to comprehend the model (Li 2000) ultimately left the financial firms vastly underestimating systemic risk. Writers such as Taleb (2008) go so far to assert that it is ultimately impossible to statistically communication uncertainty in heavy-tailed situations, an argument he advances more carefully in (N Taleb 2007). Visual representations of uncertainty in intelligence analysis are presented in (Thomson et al. 2005).

4 SIMULATION ANALYSIS EXPERIENCE

Simulation practitioners have long worked on the boundary between rigorous statistical and probabilistic means of representing uncertainty and practioners needs to make reasonable simplifications. It is a core competency of a simulation modeler's toobox to both elicit uncertainty through input modeling techniques and communicate uncertainty through output analysis techniques. A review of classic simulation texts such as (Kelton and Law 2000) and (Schruben 1995) show well established techniques in this area. For example, one approach in input modeling is to lead a subject matter expert through a discussion to characterize the broad features of an input process distribution using simple distributions such as the triangular or beta distributions.

5 PRACTIONER REALITY

Practitioners face their own challenges when trying to incorporate uncertainty analysis in their work. Even if they have the requisite self-awareness to address the uncertainty in their analysis products, the tools available may be difficult to apply. Ultimately, proper uncertainty protocols must address the challenges of the practitioner balanced against the technical capabilities of the mathematical approach. As a demonstration of stunning ability for statistical distributions to describe uncertainty, consider the wealth representations of a univariate random variable and the relationships between them as represented by Figure 1 from (Leemis and McQueston 2008). For a statistician, the figure is beautiful for the possibilities and the array of relationships, but a practitioner is likely to be squeezed by the paradox of choice (Schwartz 2005). On the one hand, a theoretical univariate is unlikely to clearly match the users needs, while the sheer volume of options will It is understandable why practitioners tend to prefer the safety of the normal distribution.

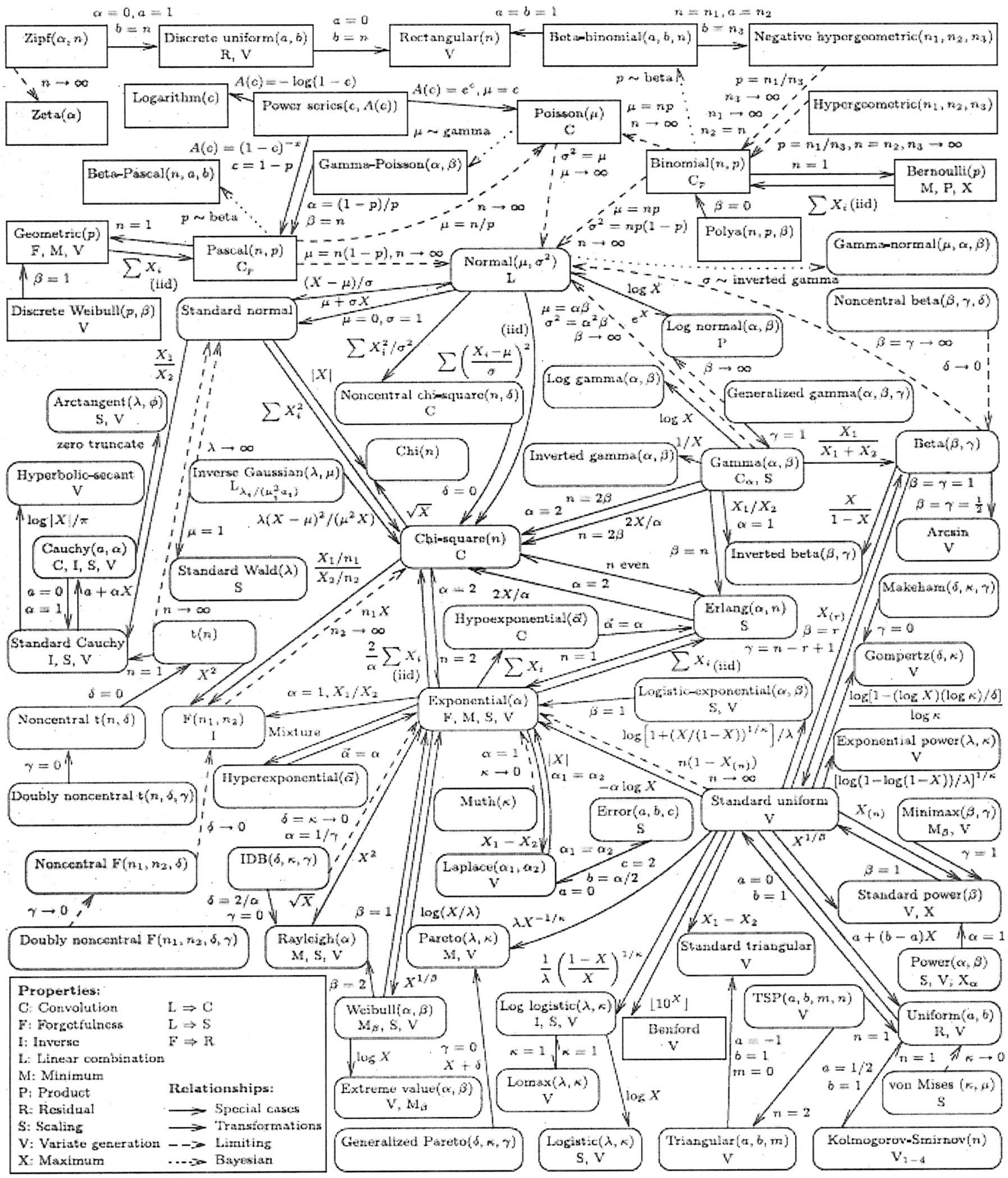

Figure 1. Univariate distribution relationships (Leemis and McQueston 2008)

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