PROPOSAL TITLE: Theoretical Models of Human-Machine Interaction in Streaming Analysis Contexts

PRINCIPLE INVESTIGATOR: R. Jordan Crouser, Smith College

SUBMITTED TO: Analysis in Motion Initiative
Attn: Kris Cook
Pacific Northwest National Laboratory

To date, the study of human intervention into computational problems has concerned itself primarily with questions of tractability. That is, does human input make it possible to (efficiently) solve problems whose solutions are otherwise believed to be too expensive to compute? Using experiential knowledge regarding the kinds of processing that humans are "better" at, such as recognizing objects and interpreting social behavior, we build systems that capitalize on these skills and offer them as constructive proof: tangible evidence that the problems are in fact tractable using human computation, even when other methods have failed. As such, the development of real-world implementations has far outpaced the development of theoretical measures. Many of these implementations have demonstrated unparalleled success at problems previously thought to be intractable, such as protein folding (Cooper et al., 2010). However, in the absence of a rigorous theory in which to ground new algorithms, researchers must rely on intuition and some deeply-rooted assumptions about the differences between human and machine computation. Extending complexity models to encompass both human and machine computation will help us understand our successes and failures on existing problems, and more fully illuminate the computational space they inhabit.

In their early research into developing theoretical foundations for human computation, Crouser et al. [1] introduced the Human Oracle Model as a method for characterizing and quantifying the use of human processing power as part of an algorithmic process. This work provides a critical first step in quantifying human involvement in computational processes, and helps us to better understand the intricate relationships among different problems and problem families when viewed through the lens of human computation. That said, it only just scratches the surface of this potentially rich area for future research. In particular, it characterizes only a small set of simple, offline problems and relies on the simplicity of the problem to serve as a bound on the human's required resources. Because of this, the existing model falls short when applied to more complex, streaming applications.

In order to more fully understand how to balance human and machine effort in online computation, it is imperative that we establish mechanisms by which we might extend these models to quantify and reason about the computation being done. Our proposed approach is twofold:

(H1) Limiting the resources (memory, time-to-decision, etc.) available to the Human Oracle will result in simulated behavior that is different from that observed in the original model.

To validate (H1) , we will explore the impact of imposing various limiting factors on the Human Oracle using simple modeling and simulation techniques. This will provide a basis for comparison with the original model, as well as generate a "tunable" testbed for future adaptations to the model.

(H2) The resource-limited Human Oracle Model enables accurate prediction of human performance on streaming data analysis tasks.

To validate (H2), we will conduct a web-based experiment using actual human subjects in which various components of a selection of streaming applications are manipulated (stream volume, sampling rate, etc.). We will then compare participants performance with that predicted by the testbed in (H1).

Through this research, we hope to gain insight about issues unique to streaming analysis and direct the search for more efficient solutions to pressing national problems. The development of complexity measures for human computation may play a significant role in the broader adoption of human computational methods. Robust models of how humans fit into the grand scheme of computational tools is essential to promoting wider understanding of human effort as a legitimate and measurable computational resource.

[1] R. Jordan Crouser, Benjamin Hescott, Remco Chang. "Toward Complexity Measures for Systems Involving Human Computation." Journal of Human Computation, Vol 1, No 1 (2014)