Collaborative Computing

Reimagining the Relationship between Analysts and their Computers

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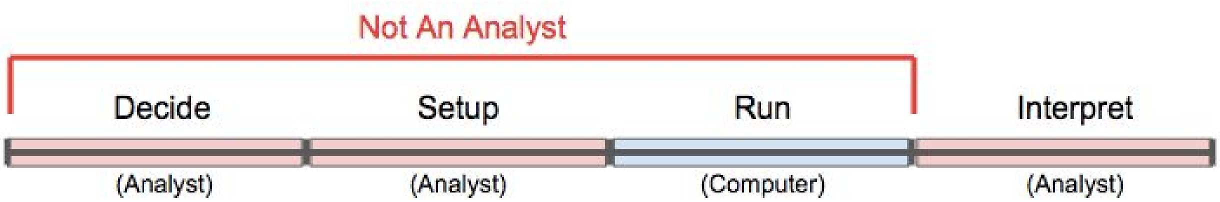
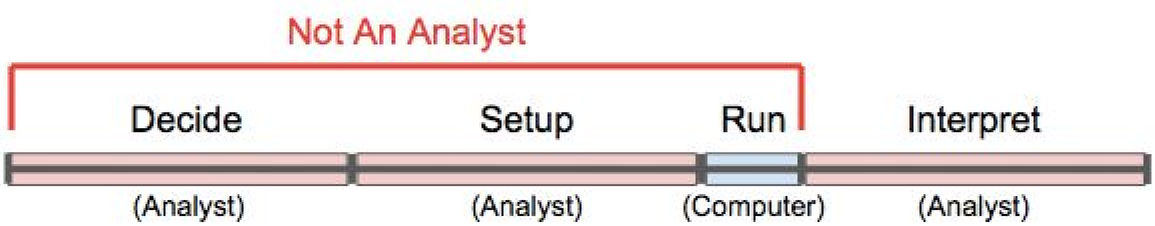
Motivation

A Growing Imbalance

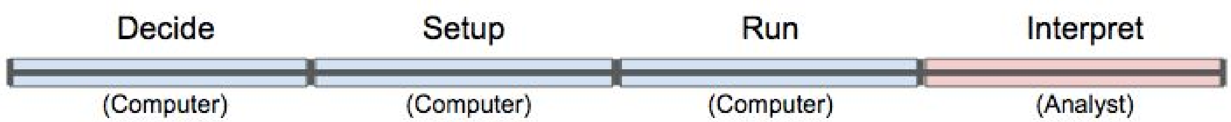


The core function of intelligence analysts is to interpret and contextualize information in order to synthesize insights that can enable decision-making. While the synthesis step is largely an internalized, cognitive process, the gathering and manipulation of data often requires the use of computerized tools such as spreadsheets, databases, and digital report archives or other lookup tools. One admittedly-simple model of the process by which an analyst utilizes a computational resource can be represented above. The analyst must first decide which computational tool to use. Next, they must setup the interaction with the tool, such as preparing and inputting query parameters or navigating a graphical interface. The third step is that the computer performs the requested action. And, finally, computational output in hand, the analyst interprets the results for relevance and either starts this process over or continues with their analysis.

Efforts at making this process more efficient for an analyst should note two important thing from this model. First, it should be noted that during the first three steps of this process, the analyst is effectively removed from the tasks that they are uniquely skilled to perform (interpretation, analysis, etc.) and are making no appreciable progress on their analytic goal. This is cost that the analyst bears in order to utilize the computational result.



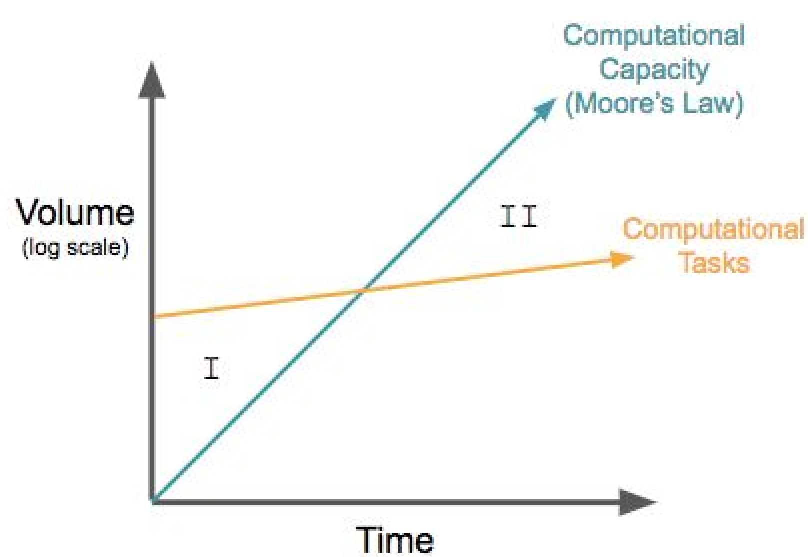
Second, because of the exponential growth of computing power, the “Run” phase is constantly getting shorter (given constant input). Additionally, this phase can benefit from parallelization and other optimization techniques to further reduce runtime. The result of this continual improvement is that for tasks that are relatively simple to compute, it can take many orders of magnitude more time for the human to pick a tool and configure it to run than it does for the tool to run.



There is a growing imbalance between intelligence analysts and the computational systems they utilize to do their jobs. Namely, that the computing speed available to analysts continues to grow at an astounding rate while human cognition enjoys no such exponential growth in capacity. In effect, the computer is waiting far more on the human than the human is waiting on the computer. This presents an opportunity. One can imagine the efficiency that could be gained if the computer were able to use its excess capacity to perform the parts of the analytic process that are currently a burden to the analyst.

Challenging a Fundamental Paradigm

The way in which we interact with computers has evolved considerably, but our expectations of them has not. When computers were first created, they represented such a great expense that they were fully utilized almost constantly. Intuitively, we understand that there were simply more tasks that required computation than the computational resources of the time could accommodate (area I). While computation is used for much more today than it was at the dawn of the computing age, the rise in computational tasks appears to have been significantly outstripped by the rise in computational capacity. This inversion of factors can be witnessed most prominently in the personal-computing realm through the fact that a significant portion of the computing devices we use on a daily basis are dormant or at least not fully utilized for the majority of any given day.



Given the relationship between these two factors: the growth in computing power and the growth in computing tasks, as time goes on, we will inevitably be left with more and more computing power being left unutilized (area `II`). In light of this, it seems appropriate to revisit the way in which we interact with computers and our expectations of them.

From Tool to Collaborator

We traditionally view the computer as a tool, something to be used by the analyst to accomplish their objectives. The computer is available to be used when the analyst needs it, but without a user initiative the computer will sit idle. In recent years, as computing power has expanded and the presence of computing has become more pervasive, we have begun to see systems that are more assistive in nature.[1]

The rise of intelligent assistants (e.g. Amazon Alexa/Echo, Apple Siri, Microsoft Cortana, Google Assistant) has demonstrated the benefit of viewing computers as assistants. These systems take on some portion of the workload or tasks of an individual or group.[2] However, most intelligent assistants still follow a delegative model of assistance, where the user decides what needs to be done.[3]

The problem of proactively deciding which computational task to perform closely aligns with the problem of recommender systems. Recommender systems are systems that involve predicting user responses to options[4]. A recommender based, proactive assistant that could autonomously decide to perform computation that the analyst would have chosen to perform would be a dramatic improvement over delegative assistants. However, these assistants would still be limited by only being able to perform as well as the user(s) they were trained on.

We propose to imagine computers not just as assistants, but as true collaborators in the analysis process. In our view, a collaborative computer would be able to decide, setup, and run analytics without requiring a human analyst to interrupt their own workflows to either initiate the computation nor to integrate the results. Additionally, the analytics chosen by the collaborative computer could include that the analyst never would or could have performed themselves. By framing the challenge as one of developing computers that can serve as intelligent collaborators

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[1] Phillips, Elizabeth, et al. "From tools to teammates: Toward the development of appropriate mental models for intelligent robots." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Vol. 55. No. 1. Sage CA: Los Angeles, CA: SAGE Publications, 2011.
[2] "What Is an Intelligent Digital Assistant? – Jack Krupansky – Medium." 30 Nov. 2017, https://medium.com/@jackkrupansky/what-is-an-intelligent-digital-assistant-3f601a4bb1f2.
[3] Myers, Karen, et al. "An intelligent personal assistant for task and time management." AI Magazine 28.2 (2007): 47.
[4] Leskovec, Jure, Anand Rajaraman, and Jeffrey David Ullman. Mining of massive datasets. Cambridge University Press, 2014.

in the analytic process we hypothesize that we can highlight foundational challenges and research areas needed to make substantial gains in analyst productivity[5,6].

Relevant Research Challenges

Identifying Analyst Activity

Any system that proactively runs computations without receiving explicit tasking by the user must have some other method of triggering the computation based on observations of the analyst's activities. A straightforward approach could collect data on the activities of an analyst that occur prior to their use of an analytic[7]. That information could then be used to predict what analytics will be part of the analyst's workflow as the analyst is performing the work. However, as the number of potential analytics to run grows larger and the behavior patterns that proceed the analytic use grow less consistent, this approach becomes less effective[8,9].

These strictly data-driven approaches could benefit from cognitive and perceptual research on how human collaborators work together. Efficient collaboration between teams is often facilitated by a shared situational awareness of the overall progress and objectives[10]. This shared situational awareness enables collaborators to decide independently on their tasking while ensuring that their work is well-coordinated[11]. The abstraction of the collaborative workflow that produces this shared situational awareness could provide the intermediate representation necessary to enable a mapping between an analyst's actions and their analytic choice.

Functional task analyses of an analysts' workflows[12] could be effective towards developing this intermediate representation. One objective of these analyses, however, should be to map both analyst activities and computational analytics to a common set of functional components. With a common set of functional components, it could be possible to (a) capture an analyst's workflow

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[5] National Research Council. 2012. Intelligent Human-Machine Collaboration: Summary of a Workshop. Washington, DC: The National Academies Press. https://doi.org/10.17226/13479

[6] National Research Council. 2014. Complex Operational Decision Making in Networked Systems of Humans and Machines: A Multidisciplinary Approach. Washington, DC: The National Academies Press. https://doi.org/10.17226/18844.

[7] Moon, Changsung, et al. "Online prediction of user actions through an ensemble vote from vector representation and frequency analysis models." *Proceedings of the 2016 SIAM International Conference on Data Mining*. Society for Industrial and Applied Mathematics, 2016.

[8] Jones, Paul, et al. "A versatile platform for instrumentation of knowledge worker's computers to improve information analysis." Big Data Computing Service and Applications (BigDataService), 2016 IEEE Second International Conference on. IEEE, 2016.

[9] Jones, Paul, et al. "Journaling interfaces to support knowledge workers in their collaborative tasks and goals." *Collaboration Technologies and Systems (CTS), 2016 International Conference on*. IEEE, 2016.

[10] Salas, Eduardo, et al. "Situation awareness in team performance: Implications for measurement and training." *Human Factors* 37.1 (1995): 123-136.

[11] Endsley, Mica R. Designing for situation awareness: An approach to user-centered design. CRC Press, 2016.

[12] Hackos, JoAnn T., and Janice Redish. User and task analysis for interface design. John Wiley & Sons, New York, 1998.

by mapping analyst activities to functional components (b) identify functional components that could be performed through analysis of the abstract workflow or comparison to other abstract workflows and (c) decide on analytics to proactively run by mapping the identified functional components to available computational analytics.

Integration of Computational Results

The corollary challenge to understanding how analyst activity should lead to proactive decisions to run specific analytics is the question of how to integrate the results of those analytics back into the analyst's workflow. One of the most difficult challenges here is scale. Without the bottleneck of waiting for analysts to explicitly request an analytic result, the system could possibly generate orders of magnitude more analytic results than an analyst can possibly perceive or interpret[13].

It may be possible to reduce the burden on the analyst by requiring the system to do more effort to filter and/or summarize the computed results. However, these approaches raise issues of their own. How does the analyst know that their collaborator is not filtering things that are relevant? How do they know that the summary covers all of the available information?

We can also foresee the questions around trust[14] becoming relevant to developing approaches here. If the computer is to become a true collaborator with the analyst, the analyst must learn to trust the computer and the computer must earn the analyst's trust. How can tools themselves incorporate mechanisms to enable this trust-building exercises?

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[13] Melguizo, Puerta, et al. "What a proactive recommendation system needs: relevance, non-intrusiveness, and a new long-term memory." In: Ninth International Conference on Enterprise Information Systems, Volume HCI, Funchal, Madeira, Portugal, June 12-16, 2007, pp. 86–91.
[14] Lee, John D., and Katrina A. See. "Trust in automation: Designing for appropriate reliance." *Human Factors* 46.1 (2004): 50-80.