Critical Actor-Network Theory: Hybrid Theory for Visual Analytics

Abstract
In this work, we introduce Critical Actor-Network Theory (CANT), a hybrid theory for Human-Centered Data Science. We outline the core components of CANT, including analysis of power dynamics and long-term impacts, reflexivity, anti-solutionism, and tracing heterogeneous networks. We also demonstrate how this theory may be applied to the design of visual analytics tools to facilitate critical analysis of biases and more impartial representation.

Author Keywords
visual analytics; critical theory; actor-network theory

ACM Classification Keywords
H.5.0 [Information interfaces and presentation (e.g., HCI)]: Theory, Design; H.1.2 [Human factors]: Theory, Design

Introduction
Visual analytics, a key discipline within Human-Centered Data Science (HCDS), provides a powerful set of tools for data analysis, but like other fields geared toward making sense of vast quantities of data, it is vulnerable to inadvertent bias. In choosing and applying visual analytics techniques to gain insight about a problem, researchers may unintentionally constrain the consideration of the problem space, limiting the scope of knowledge that may be discovered. The theory proposed in this work, Critical Actor-
Network Theory (CANT), weaves together components of Actor-Network Theory (ANT) and Critical Theory (CT). This combination can enable researchers to critically examine technologies as they currently exist, but it also provides mechanisms to help guide design.

**Hybrid Theory Development**

Critical Actor-Network Theory (CANT) is a hybrid theory that supports design and analysis. CANT supports crucial work for HCDS including: the explicit examination of power, reflection on bias, network tracing, and analysis of long-term impacts.

**Power Analysis**

Analysis of power dynamics is possibly the most significant component of CANT. ANT provides the framework for in-depth exploration of power relations. Latour explains, “[Strength] does not come from concentration, purity and unity, but from dissemination, heterogeneity and the careful plaiting of weak ties” [7]. In other words, power derives from influence. Beyond enabling the examination of power through an ANT-like framework, CANT requires a particular focus that rejects the treatment of technology as value neutral. Feenberg argues, “Social choices intervene in the problem definition as well as its solution. Technology is not ‘rational’ in the old positivist sense of the term but socially relative” [2, p. 67]. CANT analysis supports inclusiveness and democratization of technology by drawing attention to institutional biases that would otherwise remain invisible. Consideration of power and the implications of power relationships are explicit. CANT has no claim to objectivity or neutrality, but requires its adherents to examine their own assumptions and biases. The CANT framework does not constrain the outcome of power analysis, but it dictates that the analysis must be performed.

**Reflexivity**

CANT goes beyond the analysis of power in institutions and societies, requiring designers to question and challenge their own assumptions through self-reflection. Successor science, a brand of CT that Steve Harrison introduces, is the creation of new forms of science that work in opposition to codified scientific mechanisms and norms relying on gender, class, racial, and other biases. Rather than striving for objectivity or universal truths, successor science dictates that biases and contexts should be explicitly acknowledged [4, p. 387-389]. CANT also incorporates ANT support for reflexivity by allowing actors to trace their own networks [7]. With CANT, designers must examine the social context and their own hidden assumptions, continually critiquing and improving the quality of their designs.

**Anti-solutionism**

As a corollary to its principle of reflexivity, CANT includes an anti-solutionist criterion. Solutionism is an approach to problem-solving that “presumes rather than investigates” problems [8, p.6], constraining not just the solution space, but also the consideration of the problem itself. Internet-centrism is a subset of solutionism in which internet-based solutions or models are presumed to be superior to less technical propositions [8, p. 26]. Internet models are implicitly considered the ideal, without regard to how the constraints they impose differ from alternative models. In order to support comprehensive understanding of a problem before solutions are proposed, CANT relies on ANT’s framework for shifting analysis between and among distinct frames of reference [7]. CANT ensures that the exploration of the problem space is constrained as little as possible.

**Tracing Heterogeneous Networks**

In keeping with its anti-solutionist principles, CANT supports the tracing and translating of heterogeneous networks
in the same manner as ANT. Actor-networks, according to Latour, are composed of complex heterogeneous relationships between human and non-human actors [6], but the actor-network is also an entity capable of tracing and inscribing itself and other networks [7]. According to Feenberg, these networks favor certain actors' values or combine values to achieve multiple goals [2, p. 78]. Combined or competing interests shape the function and consequences of the technology [2, p. 67]. This analysis, adopted into CANT, allows designers to consider the competing priorities for a particular design, and specifically to consider how the actors and choices will impact proposed solutions.

Analysis of Long-term Impacts
In fact, design choices and competing motivations may have long-term consequences beyond a specific design solution. Feenberg describes a “technical code” as a standard that may pre- or proscribe behavior [2, p. 68]. Latour also addresses the prescription and proscription of “moral” behavior by mechanisms. He quips, “The distance between morality and force is not as wide as moralists expect; or more exactly, clever engineers have made it smaller” [6, p. 174]. Both Feenberg and Latour recognize the crucial impact design of technology plays in society. Feenberg explains, “Disciplines show traces of past social choices that have been crystallized in standards and materials...[and] a technological unconscious masks this history” [2, p. 75]. Though technology may be treated as value-neutral, it inevitably reflects cultural and societal biases. CANT requires critical analysis of the actors and motivations involved in design choices for new technologies, including particular consideration of potentially far-reaching consequences.

CANT Summary
Critical Theory (CT) and Actor-Network Theory (ANT) comprise the basis of CANT, and they are more powerful in combination with each other than individually. While CT is well equipped to support analysis of bias, its implications for design are indirect. ANT facilitates exploration of heterogeneous networks of actors (both people and artifacts), and it has direct implications for the prescription or proscription of behavior through design. CANT is thus situated to help theorists critically analyze complex systems with an eye toward developing more inclusive and fair solutions.

Design Issues in Visual Analytics
Visual analytics, like other areas in HCDS, is vulnerable to designer bias. In particular, the solution space for visual analytics tools and techniques may be constrained by designers’ unfounded assumptions about the problem. Since designers’ assumptions are often invisible to them, the biases reflected in tools may compound and exacerbate unintended consequences.

Selective Representation
The visualization component of visual analytics is usually the key to human comprehension. As Stephen Few explains, “Vision is not only the fastest and most nuanced sensory portal to the world, it is also the one most intimately connected with cognition” [3, p. 29]. Choice of visual representation may critically impact the cognitive effort required to make sense of data. Both Few and Rogers are careful to point out the limitations of graphical representations. Rogers describes “graphical constraining” as the limitation that a graphical representation may impose on the insight that can be gained about the underlying information [9, p. 34]. Few notes, “Traditional data analysis tools make it unnecessarily difficult to explore data from multiple perspectives, so analysts tend to pursue only a limited set of predetermined questions” [3, p. 104]. In other words, poorly designed visualizations restrict thinking. Although bias cannot be completely eliminated, the effects of the bias
should be mitigated to the extent possible in order for a visualization to fulfill its goals.

CANT’s principles of reflexivity and actor-defined network-tracing support more inclusive representation. The reflexivity component of CANT encourages designers to explicitly consider their own biases. The principle that actors trace their own networks and contribute to the meaning-making process about themselves should also encourage fuller representation of data. The application of CANT requires open acknowledgment of selectivity and biases. CANT dictates a critical analysis of implicit and explicit power dynamics in representation. The biases and selectivity may not be eliminated, and in fact, critical examination does not even guarantee that they will be recognized. However, the explicit requirement that application of CANT include analysis of power and bias should mitigate the risks of selective representation. It should also challenge the designers’ initial assumptions about the problem, so that the ultimate design is likely to yield greater insight into the data than it otherwise could have.

**Compounded Bias**

The compounding of bias is another inevitable risk in machine learning and visual analytics systems. Since computers generally run deterministic, verifiable programs, they are assumed to be quantifiably “correct.” But humans with human biases write the programs, input data, and interpret outcomes. H. V. Jagadish and Cynthia Dwork present examples of “unbiased” algorithms that nevertheless yield biased results. Jagadish gives the example of a hiring algorithm [5], while Dwork offers a similar example of university admissions programs [1]. Ultimately, none of the data used to train these machine learners is unbiased. When a machine is trained that minority candidates are undervalued or underpaid, it will generally make recommendations that harm minority candidates. In many cases, algorithms actually compound the biases within the original data.

The key to understanding this weakness in visual analytics is recognizing the social context of the technology. CANT rejects the premise of “neutrality” of technology. It also requires explicit analysis of power dynamics inherent in data collection and data analysis, so with the application of CANT, minorities and other vulnerable populations are likely to receive fairer treatment. CANT also rejects the internet-centrist bias toward big data analysis and acknowledges the potential prescription and proscription of behavior by technology. Moreover, CANT presumes that actors, in tracing their own actor-networks, determine the meaning of their own existences and so may help shape design choices of technology. As in the example of selective representation, this inclusion of concerned parties supports the design of better, more representative visual analytics systems.

**Conclusion**

In this work we introduced a new hybrid theory for Human-Centered Data Science, Critical Actor-Network Theory (CANT). Incorporating components from Critical Theory and Actor-Network Theory, CANT supports rigorous analysis of assumptions and biases, and it rejects the presumption of technology as neutral. Fulfilling the tenets of CANT requires analysis of heterogeneous networks and long-term impacts. CANT may be applied to mitigate the vulnerabilities of visual analytics systems to selective representation and compounded bias, and it has broader implications for technology design in general. CANT requires reflexivity in designers, and the inclusion of concerned groups in CANT analysis is highly recommended. CANT analysis has been developed to foster inclusion and fairness in technology design, and it is also intended to support broader exploration of problems before solutions are sought.
REFERENCES


