Dynamic natural kinds: Open-ended evolution in the joints of nature

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Abstract

This note defends the dynamical natural kinds (DNK) hypothesis that some natural kinds are dynamic and correspond to clusters moving in feature space. Philosophers invented the term *natural kind* for categories that "carve nature at its joints," i.e., categories that objectively explain the typical features of their instances. The DNK hypothesis is inspired by recent scientific work on classifying technology by statistical analysis and modeling of patent documents (Bedau, Gigliotti et al. 2019), which demonstrated striking non-random movement of technology clusters in a technology feature space. This note describes the DNK hypothesis and summarizes how it is supported by dynamic technology clusters and by the contrast with alternative approaches to natural kinds and biological species.

The dynamic natural kinds hypothesis

This note concerns kinds (groups or categories of things). Organisms and chemicals, for example, each come in many kinds. Some kinds are merely idiosyncratic groups invented by humans, such as organisms categorized by longitude of birth, or chemicals categorized by color. But philosophers consider some kinds to be *natural*. Not merely human inventions, natural kinds would figure in the natural world even if humans had never existed. Plato vividly described them as "carving nature at its joints."

This note investigates what we can learn about natural kinds from recent work on classifying things that are evolving. In particular, when Bedau, Gigliotti et al. (2019) used methods from natural language processing (NLP) and machine learning to classify the past forty years of technological innovations, they noticed some technology clusters moved non-randomly in technology space. This scientific observation inspires a philosophical hypothesis:

> **dynamical natural kinds (DNK):** some natural kinds are dynamic and correspond to the non-random movement of a cluster in feature space.

This extended abstract summarizes a recent defense of the DNK hypothesis (Bedau 2020).

Philosophers today defend many different theories of natural kinds (Ellis 2001; Dupré 2001; Hacking 2002, 2006; Ereshevsky 2001; LaPorte 2004; Elder 2005; Devitt 2008; Love 2009; Campbell et al. 2011; Kendig 2011; Khalidi 2013; Slater 2013; Franklin-Hall 2015; Haber 2016; Austin 2019). This paper assumes that natural kinds must meet two familiar and widely accepted conditions, one about *objectivity* (natural kinds reflect not merely how humans choose to classify things) and the other about *explanation* (natural kinds predict and explain their member's typical features). Many also accept a *stasis condition* (the objective explanatory properties of a natural kind are fixed). This condition states that the joints of nature never change their intrinsic properties. The number of their instances might fluctuate, but those are merely extrinsic changes in the environment, not changes in the intrinsic features of a natural kind. Changes in the purposes or interests humans have in natural kinds are similarly extrinsic. The DNK hypothesis explicitly contradicts the stasis condition; it states that some natural kinds change their intrinsic objective explanatory properties, i.e., the properties that make them a specific natural kind. When a natural kind's intrinsic properties change, so do its predictions and explanations.

The traditional perspective on natural kinds accepts the objectivity, explanation, and stasis conditions, but it's distinctive hallmark is a further *essence condition* that equates natural kinds with abstract essences or essential properties. Essences give traditional natural kinds sharp and definite boundaries. Biological species illustrate their main problem. Although species boundaries are somewhat blurry and indefinite, you can still predict and explain a lot about an organism from its species. Insisting on sharp boundaries blinds the traditional perspective to the objective explanatory quality of biological species.

A typical response to this problem is to drop essences and instead ground natural kinds in imprecise clusters of the properties shared by their instances (e.g., Boyd 1999a,b; Magnus 2012; Mayr 1994); this brings biological species within reach. However, cluster-based accounts of natural kinds have their own characteristic difficulties, such as stable variation within a species (e.g., developmental stages and sexes). But their main problem is simply to identify properly principled clusters that fit the familiar paradigm cases. The following case study suggests a new way to achieve this.

Dynamic clusters of technology: a case study

Our case study (Bedau, Gigliotti et al., 2019) investigated the evolution of technology through textual analysis of patent documents, which served as a convenient proxy for the inventions described. Patented technology has been proposed as a model system for the study of cultural evolution (Bedau 2019). Algorithms from NLP and machine learning (Mikolov, Sutskever, Chen, Corrado, and Dean 2013; Le and Mikolov

2014) were used to produce a high-dimensional technology feature space, constructed so as to maximize the following property:

proportionality property: The proximity of patent documents in technology space is proportional to the similarity of the inventions described in the documents.

It is a contingent matter to what extent the proportionality property holds for the technologies described in specific documents that are embedded in a specific feature space.

The proportionality property is illustrated in Figure 1, which is a tSNE projection of centroids of patent clusters scattered through a 300-dimensional technology space. The centroids fall into evident local groups, and microanalysis shows that different groups correspond to clusters of different kinds of technologies. Figure 2 adds human-created verbal labels for a few groups. Different groups indicate different clusters of technologies persisting in different regions of technology space.

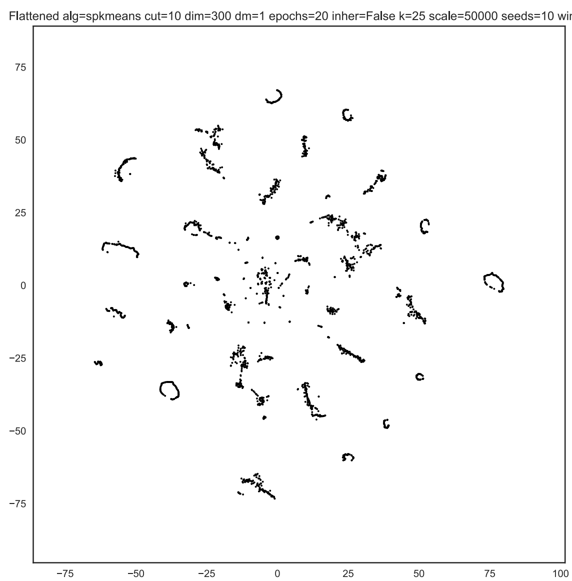

Figure 1. A tSNE projection of the centroids of clusters found in patents embedded in 300d technology space, trained on the patent corpus. Reproduced from Bedau, Gigliotti et al. 2019.

Figure 2 shows how clusters move in technology space, by encoding the issue date of the patents in each cluster with a grayscale shade (time moves from black to white). Dark groups show a cluster that went extinct (e.g., the packing and stacking cluster), and light groups indicate a new emerging cluster (e.g., molecular genetics). Figure 2 shows various kinds of cluster motion. Some appears random, but non-random motion in the 300-dimensional technology space has been confirmed for some clusters. For example, Figure 2 shows that the communications cluster originally centered on audio technology (A), but later spun off sub-clusters for digital media (B), communication networks (C), and on-line publication (D). This illustrates how the characteristic properties of a technology cluster enable us to predict and explain the typical features of certain inventions, and how those predictions and explanations can change and evolve.

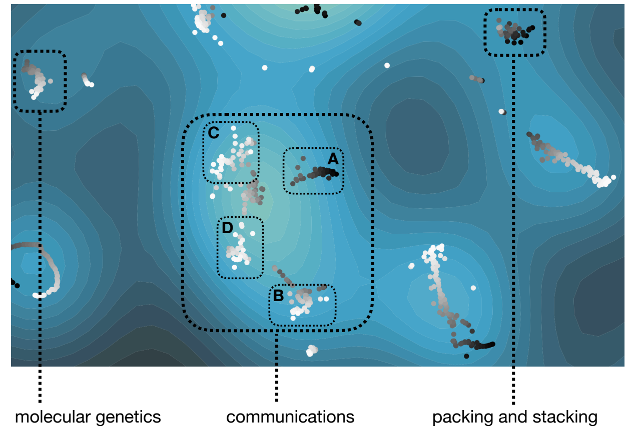

Figure 2. Blow-up of part of the tSNE projection in Figure 1; contour lines indicate the kernel density estimation, and centroid color indicate time frames (from black to white). Capital letters label sub-clusters for (A) audio technology, (B) digital media technology, (C) technologies for communication networks, and (D) on-line publication. Modified from Bedau, Giliotti et al. (2019).

Evidence for the DNK hypothesis

There are two main reasons to believe the DNK hypothesis (see Bedau 2020 for more details). The first is simply the existence of dynamic clusters of technology that the case study demonstrated. Those clusters fit the objectivity and explanation conditions that are the principle hallmarks of natural kinds, so if patent documents are accurate descriptions of inventions, then dynamic technology clusters look like dynamic natural kinds. Secondly, the DNK hypothesis compares favorably with its static essence- and cluster-based competitors, because it shares their virtues but avoids their vices. In particular, the NLP and machine learning algorithms produce clusters that are both properly principled and fit paradigms cases including biological species.

The DNK hypothesis assumes natural kinds are real, objective, empirically grounded explanatory properties. Many are static and unchanging, but some are dynamic and undergo a process of generation, change, and destruction. The result is a philosophical picture in which some of the very “joints of nature” exhibit on-going and open-ended evolution.

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References

Austin, Christopher J. 2019. *Essence in the age of evolution: A new theory of natural kinds*. Routledge.

Bedau, Mark A. (2019). "Patented technology as a model system for cultural evolution." In A. C. Love and W. C. Wimsatt, eds., *Beyond the meme: Development and structure in cultural evolution*, Minnesota Studies in the Philosophy of Science, Vol. 22, pp. 237-260, University of Minnesota Press.

Bedau, M. A. (2020). Dynamic natural kinds. Submitted.

Bedau, Mark A., Nicholas Gigliotti, Tobias Janssen, Alec Kosik, Ananthan Nambiar, Norman Packard. (2019). "Open-ended evolution of technology", *Artificial Life* 25: 33-49.

Boyd, Richard. (1999a). "Kinds, complexity and multiple realization". *Philosophical Studies* 95: 67-98.

——— (1999b). "Homeostasis, species, and higher taxa". In Wilson ed., 1999, pp. 141-185.

Campbell, Joseph, Michael O'Rourke, and Matthew Slater, eds. 2011. *Carving nature at its joints: Natural kinds in metaphysics and science*. MIT Press.

Dupré, John. (2001). "In defense of classification". *Stud. Hist. Phil. Biol. & Biomed. Sci*. 32: 203-219.

Devitt, Michael. (2008). "Resurrecting biological essentialism". *Philosophy of Science*, *75*(3), 344-382.

Elder, Crawford. 2005. *Real natures and familiar objects*. MIT Press.

Ellis, Brian. (2001). *Scientific essentialism*. Cambridge University Press.

Ereshefsky, Marc. 2001. *The poverty of the Linnaean hierarchy: A philosophical study of biological taxonomy*. Cambridge University Press.

Franklin-Hall, Laura R. (2015). "Natural kinds as categorical bottlenecks". *Philosophical Studies* 172 (4): 925-948.

Haber, M. H. (2016). "The individuality thesis (3 ways)". *Biology & Philosophy*, *31*(6), 913-930.

Hacking, Ian. (2002). *Historical ontology*. Harvard University Press.

——— (2006). "Kinds of people: moving targets". *Proceedings of the British Academy* 151: 283-318.

Kendig, Catherine, ed. (2016). *Natural kinds and classification in scientific practice*. Routledge.

Khalidi, Muhammad Ali. (2013). *Natural categories and human kinds: Classification in the natural and social sciences*. Cambridge: Cambridge University Press.

LaPorte, Joseph. 2004. *Natural kinds and conceptual change*. Cambridge University Press.

Le, Quoc and Tomas Mikolov, (2014). "Distributed representations of sentences and documents", *Proceedings of the 31st International Conference on Machine Learning (ICML-14)*, 1188–1196.

Love, Alan C. (2009). "Typology reconfigured: from the metaphysics of essentialism to the epistemology of representation". *Acta biotheoretica*, *57*(1-2), 51-75.

Magnus, P. D. 2012, *Scientific enquiry and natural kinds: From planets to mallards*. Palgrave Macmillan.

Mayr, Ernst. (1994). "Typological versus population thinking". In E. Sober ed., *Conceptual issues in evolutionary biology*, pp. 157-160. MIT Press.

Mikolov, Tomas, Ilya Sutskever, Kai Chen, Greg S Corrado, and Jeff Dean. (2013). "Distributed representations of words and phrases and their compositionality", *Advances in neural information processing systems*, 3111–3119.

Slater, Matthew. 2013. *Are species real? An essay on the metaphysics of species*. Palgrave Macmillan.

Wilson, Robert A. , ed. (1999). *Species: New interdisciplinary essays*. The MIT Press.