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Something New Under the Sun

A Category Theoretic View on Innovation and Unpredictability

Innovation can create things that did not exist before. Innovation therefore produces "ontological expansion" where qualitatively new things become real and start to play a role in social and economic development. Fifteen years ago presidents did not tweet, bloggers did not exist, and search engines did not know what you have been thinking. In earlier work (Tuomi, 2012; 2002), we have shown that the history of technology and innovation is full of such emergent steps that create qualitative novelty and expand our ontological reality.

In the present work we show how such emergence can be rigorously modeled. We thus lay new foundations for innovation and futures studies. Rigorous modeling of novelty requires an approach where systems can be more than the sum of their parts. We use a branch of mathematics, Category Theory, to show how qualitatively new elements can emerge in an evolutionary system.

Using this approach, we can describe what kinds of models can capture novelty. For example, we can show that typical forecast and equilibrium models are unable to capture innovation. This has important policy implications.

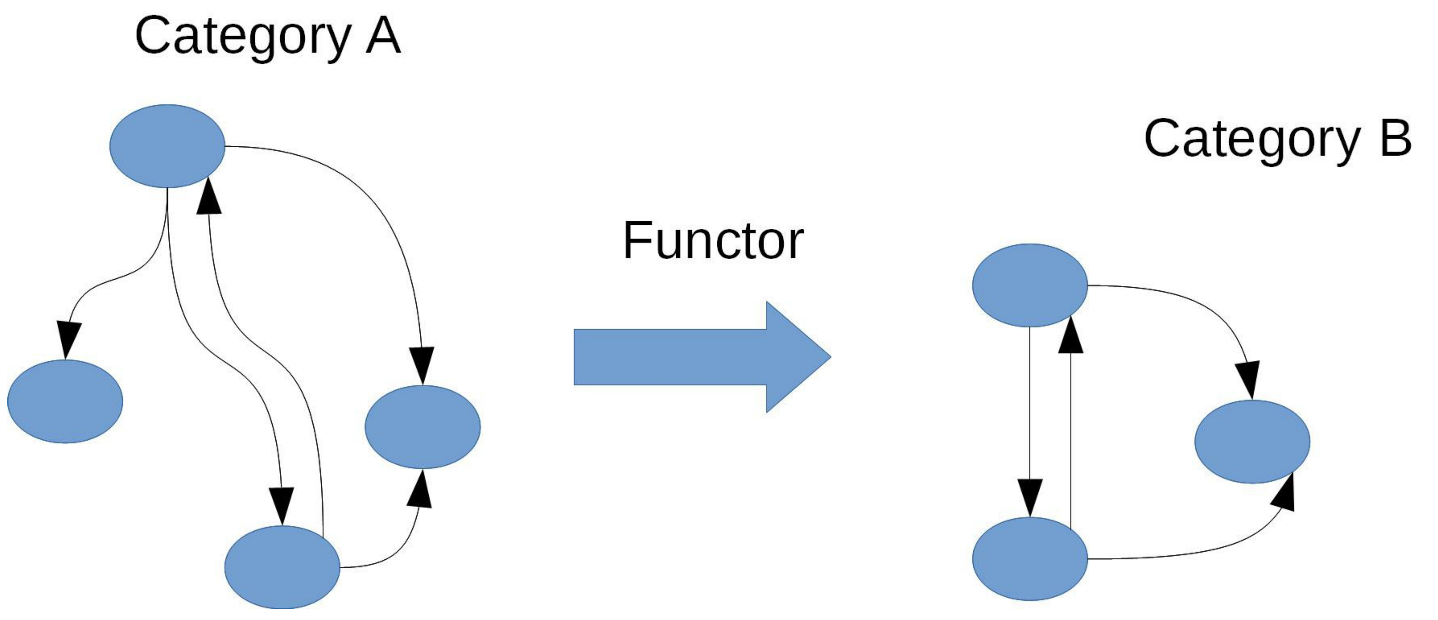
Category Theory

Category Theory (CT) is an abstract language that can be used to describe and analyze structure-preserving mappings across many different types of systems. A "category" in CT consists of "objects" and "directed arrows" that can be understood as generalized functions. When the arrows follow some simple and quite universal rules, the system of objects and arrows becomes a well-defined category. A large body of theoretical results can then be applied to study a system modeled as a category.

CT is extensively used in mathematics, logic, computer science, and increasingly in various applications. One of the earliest applications outside mathematics was by Robert Rosen in his work on living systems in 1958, and later in his landmark study, Anticipatory Systems (1985).

Ehresmann and Vanbremeersch (2007) have shown that when a system has "multifold" objects, collective functionality in a category-theoretic system can not be reduced to the functionality of its elements. Multifold objects are objects that have multiple realizations. For example, when two "microstates" lead to the same "macrostate," the system has emergent characteristics.

Elements of Category Theory



Multifold objects in multifocal innovation

Earlier work on innovation (Tuomi, 2002) has argued that innovation happens when social practice changes. Different latent user groups have different interpretations of a new technology, and technology development is driven by the capability of potential user communities to realize latent opportunities. This leads to the "multifocal" model of innovation that emphasizes knowledge creation, social learning, and innovative sensemaking in downstream communities of practice.

In the multifocal innovation model, a single technical artifact can embody multiple alternative social uses. For example, a "mobile phone" or the "Internet" can be used in many different ways and for different purposes by their different user groups. The artifact or technical system can have multiple parallel developmental paths associated with the different social uses where it is deployed. When an innovation is modeled in its social context, it has, in general, several realizations. The appropriate unit of analysis is "innovation-in-use" and a single artifact or system can have multiple identities.

A CT model of innovation, therefore, contains multifold objects. The overall system has emergent characteristics.

Implications and ongoing work

CT shows how ontological expansion can be rigorously modeled, and provides a formal justification for the claim that future is not only uncertain but unpredictable. At present, we are developing tools and foresight methods that address this challenge.

A specific focus in our "The New New Growth" project, funded by Tekes, is on modeling the evolution of innovation ecosystems, with the aim to lay foundations for "next-generation" innovation policy. CT shows that ecosystems can not be mapped to dynamical systems without losing their structure and dynamics. Conventional quantitative models, therefore, cannot model ecosystem dynamics or the expected impact of innovation. We need relational models and category theoretic foundations for robust innovation policy.

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