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Innovation Beyond Intention: The Role of Exaptation in Technological Advancements

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***Field**: AI applications to science and innovation*

Extended Abstract

The frameworks that explore scientific and technological evolution suggest that discoveries and inventions are intrinsic processes, while the wealth of knowledge accumulated over time enables researchers to make further advancements, echoing Newton's sentiment of 'standing on the shoulders of giants'. However, contrary to this view, Park et al.'s (2023) research challenges this notion, revealing that despite the exponential growth in new scientific and technical knowledge, there is a concerning decline in the disruptiveness of papers and patents by the measure of CD index proposed by Funk et al. (2017). borrowed from biological evolution, is now recognized as a pivotal yet often neglected mechanism in technological evolution. Significant technologies often do not emerge out of thin air, but rather result from applying existing technologies in other domains. For instance, bird feathers initially served for waterproofing and insulation before enabling flight, and microwave ovens originated from radar magnetrons. Exaptation signifies a cross-field evolutionary process, driven by the functional shift of pre-existing knowledge, technology, or artifacts.

In our analysis of 3,069,324 patents from 1980 to 2010 that cited prior patents sourced from the USPTO's Patents View, we expand the concept of exaptation, and introduce the 'exaptation value', which not only uses citations like other bibliometric methods, but also takes into account the patent's content similarity and field distance. This metric quantifies the extent of cross-field knowledge the focal patent inherits from its antecedents. Contrary to the downtrend in disruptiveness depicted in Fig 1.a, the average exaptation maximum value (EMV) of patents has been increasing, as shown in Fig 1.b. This indicates that technologies are progressively infiltrating diverse fields, and as the breadth of these fields expands, technological development continues to build upon the foundational work of past giants, venturing into novel territories. We utilize a pre-trained NLP model to embed the abstracts of all patents and calculate the content similarities between patents and their cited patents. Employing the CPC code as the standard, we ascertain the 'field distance' for all patents and their predecessors. The 'exaptation value' between a patent and its predecessor is calculated based on two dimensions: content similarity and field distance. We establish the EMV as a standard measure and compute the annual average EMV for each category following the NBER classification. Additionally, we illustrate the application of exaptation value analysis with a case study presented in Fig 2. We examine three patents (Monsanto, PageRank, Axel) provided by Funk et al. (2017), each exhibiting distinct CD values. These patents contribute differently to the exaptation value for their successors. Notably, the impact of a patent with a low CD value on its descendants is no less significant than that of a patent with a high CD value. The contribution of this study lies in defining a methodology to measure exaptation, providing insights into the diffusion and progression of technology from the lens of technological evolution. This approach enables the exploration of technological accumulation processes and the trajectory of technological advancement, as well as the examination of the innovation and evolutionary journey of entities that encompass both content and domain information.

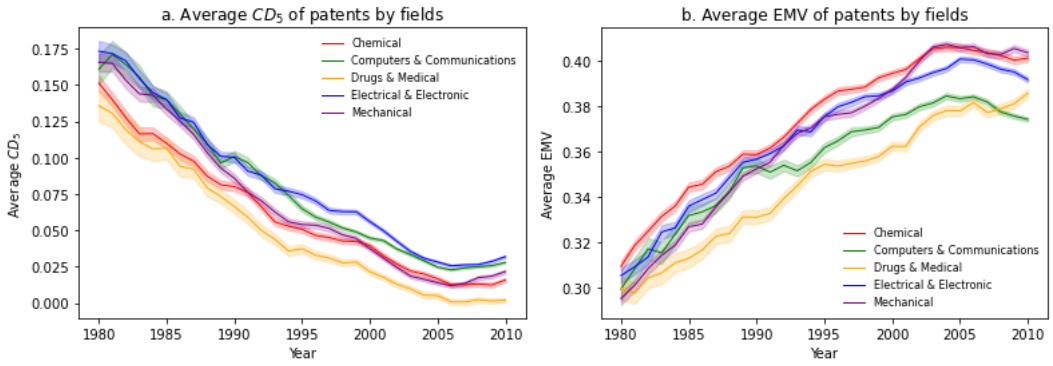

Fig 1. Decline of disruptive and incline of exaptive technology. The lines correspond to National Bureau of Economic Research (NBER) technology categories; the patents (n=3,069,324) that have not cited other patents are excluded; from 1980 to 2010 the magnitude of CD5 decline ranges from 81.6% (electrical and electronic) to 98.5% (drugs and medical) in a, while EMV incline ranges from 25% (computers and communications) to 36.7% (mechanical) in b. Shaded bands correspond to 95% confidence intervals.

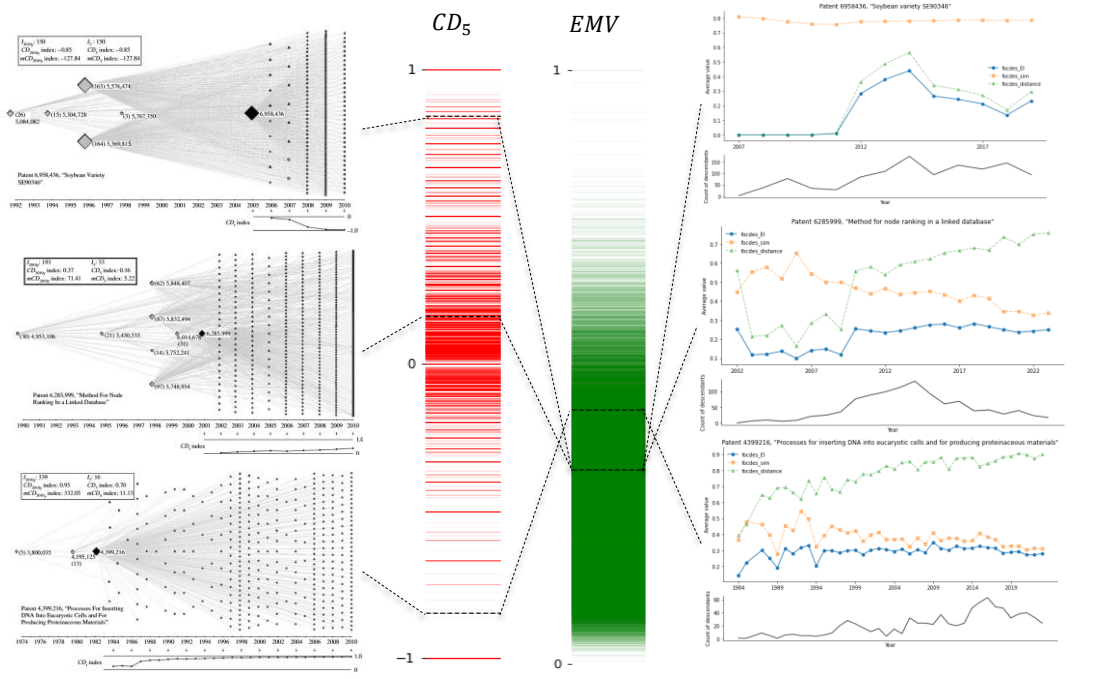

Fig 2. The case study of exaptation value approach. Three patents which are Monsanto (Top), PageRank (Middle), and Axel (Bottom) are shown on both the left and right sides. These patents are with different CD_5 and EMV. The network diagrams of these patents are on the left; In the middle, it shows their positions in the CD5 and EMV distributions; On the right, it shows their exaptation values contributing to the successors.

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