INNOVATION BEYOND INTENTION: THE ROLE OF EXAPTATION IN TECHNOLOGICAL ADVANCEMENTS

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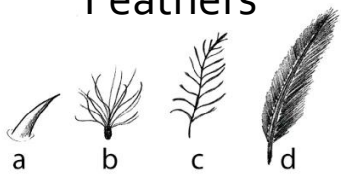
BACKGROUND

Exaptation in biology

- In biology, a structure that evolved in one context and was later adapted to another function is referred to as exaptation (Gould and Vrba, 1982).
- For instance, dinosaurs evolved **feathers** as insulation against extreme temperatures, as birds evolved from small dinosaurs, feathers changed through natural selection to give flight.

Feathers



Examples of feather types observed in the fossil record: (a) – single filaments, (b) tufted, (c) branched, symmetrical and (d) asymmetrical (flight) feathers. Not all types known are shown here.

Reconstruction of a feathered dinosaur. Chung-tat Cheung and Yi Liu

Insulation

Over time

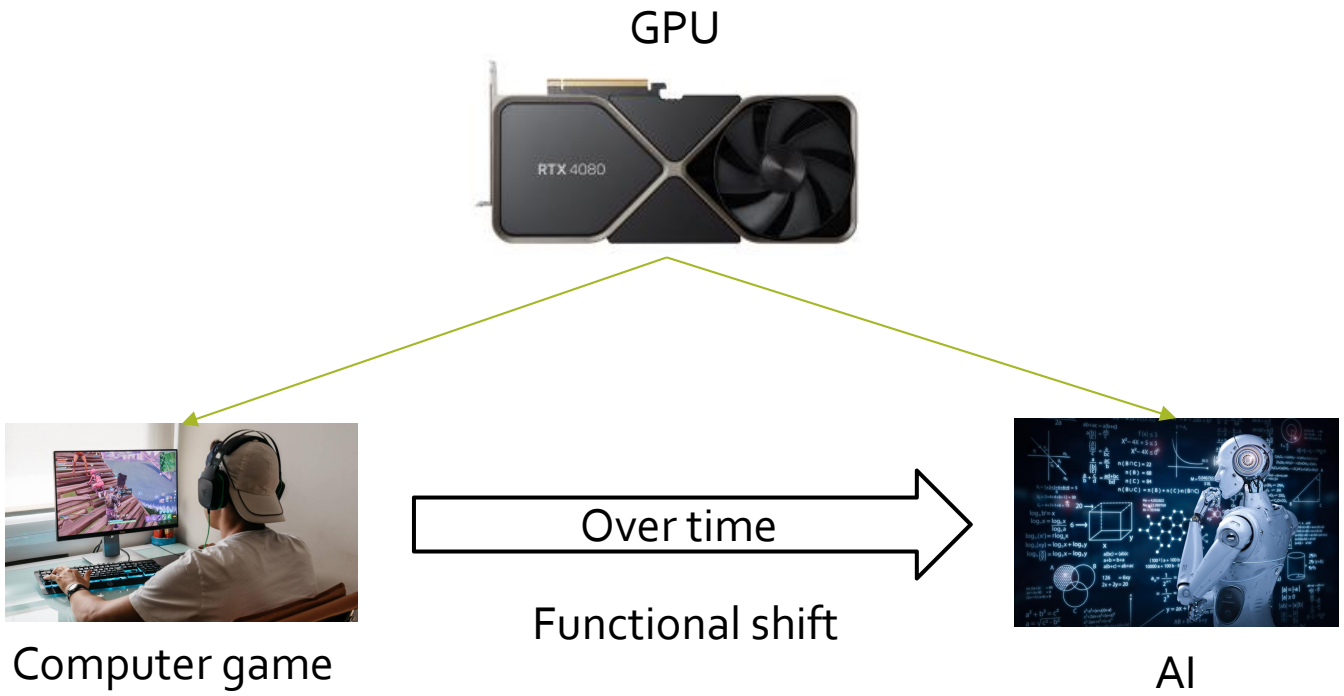
Functional shift

Flight

Exaptation: Innovation Beyond Intention

- In the field of technology, exaptation is a source of creativity and innovation (Andriani and Cattani, 2016), showcasing a mechanism where technology is repurposed for a different use. Because it deviates from its original function, it represents an innovation that is beyond the initial intention.

- "Great innovation is built on existing ideas, repurposed with vision".— Jake Knapp from Google Ventures and author of the book "Sprint"



RESEARCH QUESTIONS

Research questions

- Over time, the disruptiveness of innovations decreases but the exaptation increases.
- Highly exaptive patents may not be considered disruptive at first.
- Highly exaptive patents have the potential for continued disruptive growth.

DATA AND METHODS

Data

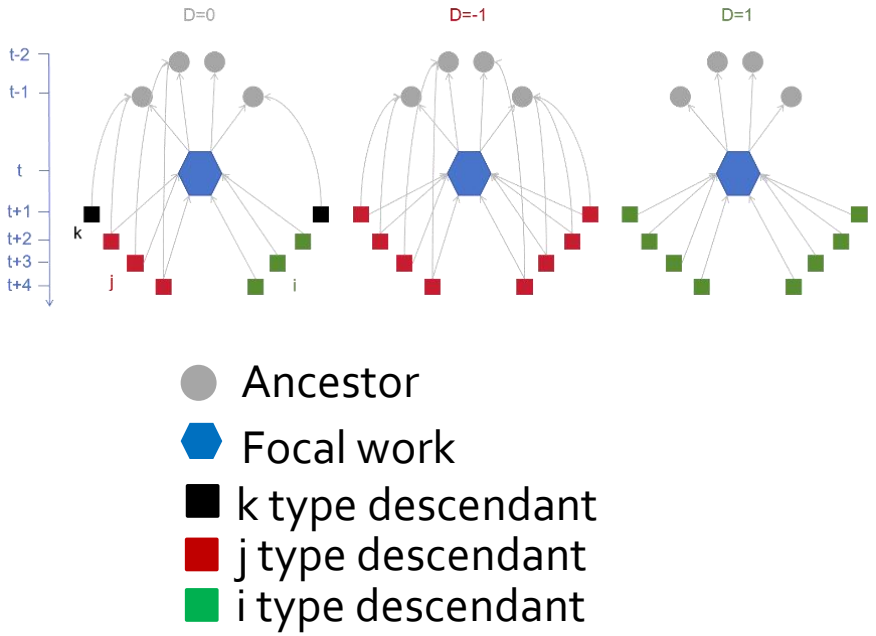
- USPTO patents (1980-2010): 3,661,268
- Patents which have CD_5 index and ancestor: 3,420,673
- Patents which have CD_5 and belongs to the 5 NBER technology category: ['Chemical', 'Computers & Communications','Drugs & Medical', 'Electrical & Electronic', 'Mechanical']

Methods

- The CD index proposed by Funk and Owen-Smith gauges the disruptive impact of science and technology through citation networks (Funk and Owen-Smith, 2017; Wu et al., 2019). It shows the disruption of the focal innovation.

$$CD = D = \frac{n_i - n_j}{n_i + n_j + n_k}$$

Where n_i refers to the count of descendants that cite the focal work; n_j refers to the count of descendants that cite the focal work and also the focal work's ancestor; n_k refers to the count of descendants that cite the focal work's ancestor but not the focal work.



Methods

Exaptation value:

We measure the exaptation value as the product of the content similarity and field distance between the focal node and its ancestor. The greater the similarity in content, the higher the value of exaptation. Conversely, the greater the distance within the functional field, the higher the exaptation value.

$$E_{i,k} = c_{i,k} \cdot d_{i,k}$$

Where i is the focal node, k is an ancestor of the focal node

$c_{i,k}$ is the **content similarity** of node i and k. It's the cosine similarity of the patent abstracts processed by a pre-trained NLP model known as Sentence Transformer (Reimers and Gurevych, 2019).

$d_{i,k}$ is the **field distance** of node i and k. We calculate it by the Jaccard similarity of the patent CPC codes.

Methods

- Maximum exaptation value (inventor's most significant effort to incorporate knowledge from other fields):

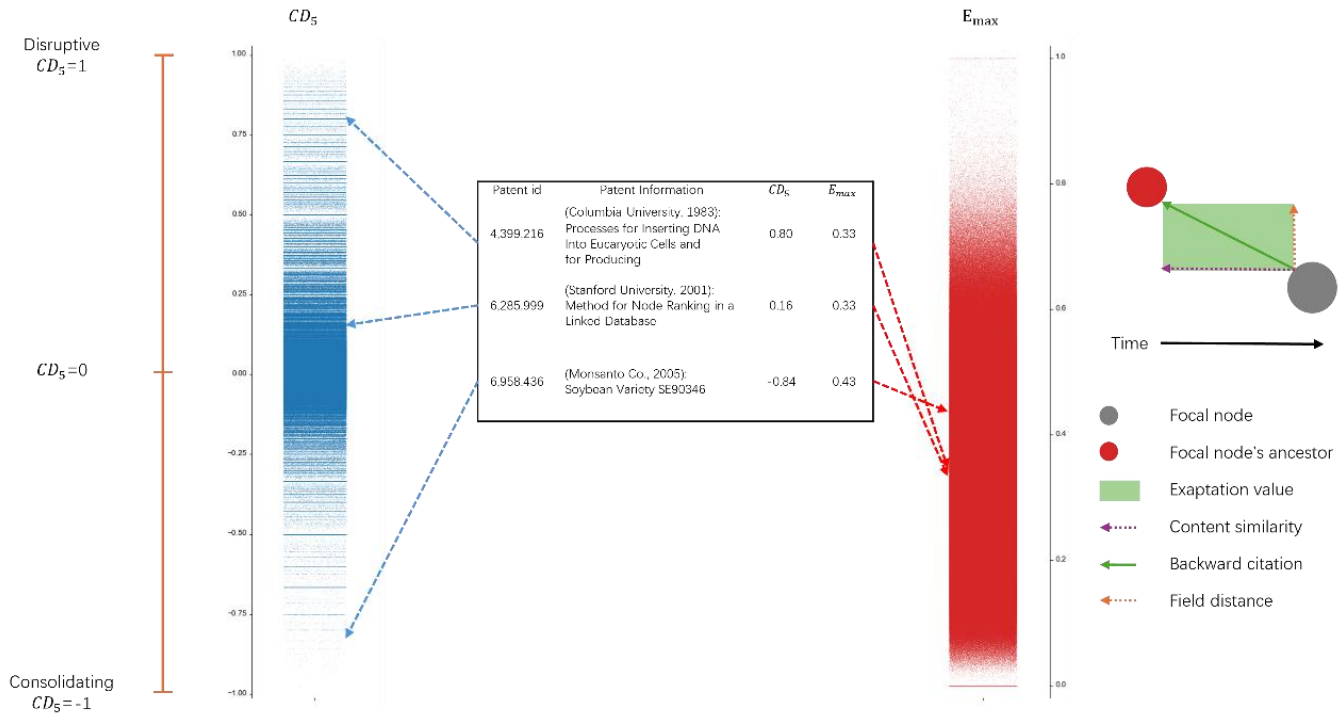
$$E_{max}(i) = CS_{i,k^+} * FD_{i,k^+}$$
$$k^+ = argmax_{k \in X}(CS_{i,k} * FD_{i,k})$$

- Minimum exaptation value (baseline for exaptation driven innovation):

$$E_{min}(i) = CS_{i,k^-} * FD_{i,k^-}$$
$$k^- = argmin_{k \in X}(CS_{i,k} * FD_{i,k})$$

Distributions of CD index and maximum exaptation value

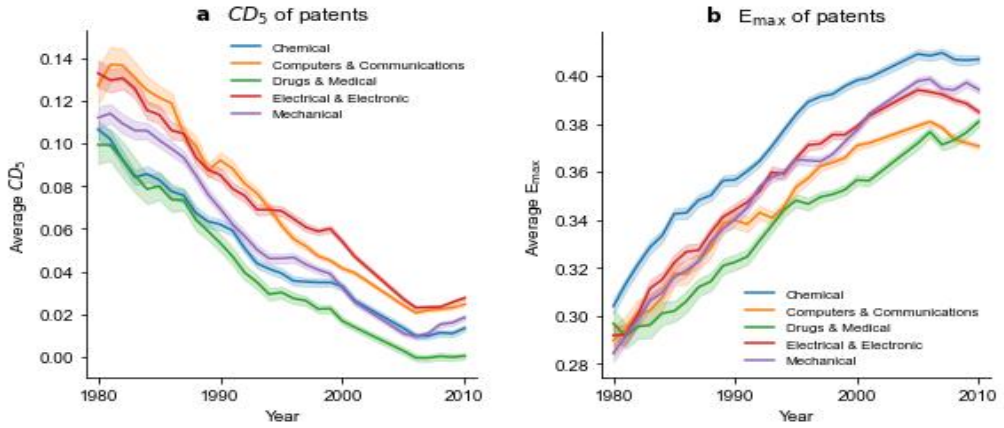
CD index and maximum exaptation value:



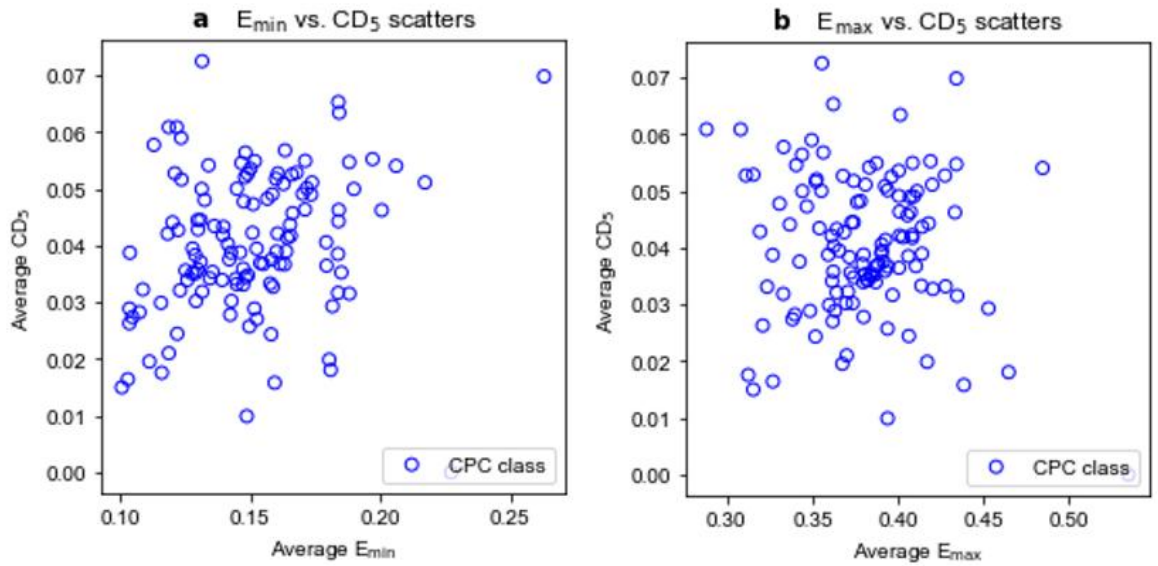
RESULTS

Disruption decreases while exaptation increases over time

- Park et al.'s (2023) research reveals that despite the exponential growth in new scientific and technical knowledge, there is a concerning decline in the disruptiveness of papers and patents.
- Concurrently, our study observes an increase in the average maximum exaptation value, which suggests that inventors are increasingly striving to integrate knowledge from diverse fields.

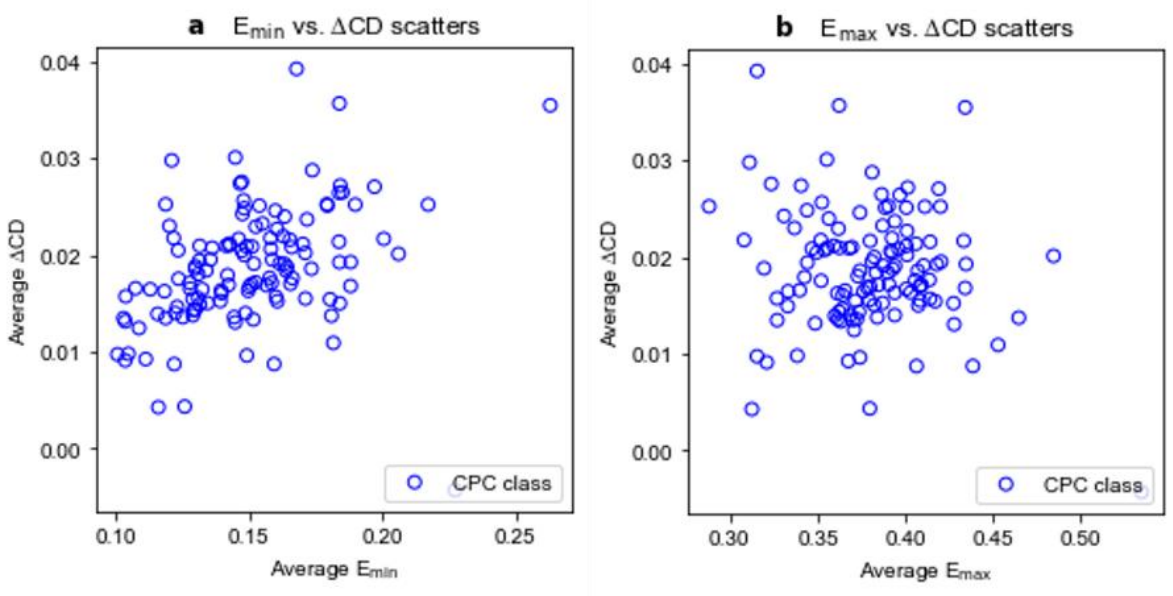


Highly exaptive patents may not be considered disruptive at first.



a, for USPTO patents from 1980 to 2010 (n=3,420,673), it shows the scatters of average CD_5, and average E_{min} values classified in 124 CPC classes.
b, it shows the scatters of average CD_5 and average E_{max} values classified in 124 CPC classes.

Highly exaptive patents have the potential for continued disruptive growth.



$$\Delta CD = CD_{10} - CD_5$$

ΔCD: The CD index growth can show the potential for continued disruptive growth.

a, for USPTO patents from 1980 to 2010 (n=3,420,673), it shows the scatters of average ΔCD, and average E_{min} values classified in 124 CPC classes.
b, it shows the scatters of average ΔCD and average E_{max} values classified in 124 CPC classes.

Regressions

Dependent variable: CD_5 of each patent
All variables are at the patent level.

	(1)	(2)	(3)	(4)	(5)	(6)
Minimum exaptation	0.0739***	0.0764***				
	(0.0011)	(0.0011)				
Maximum exaptation			0.0090***	0.0120***		
			(0.0007)	(0.0007)		
Average exaptation					0.0395***	0.0435***
					(0.0009)	(0.0009)
Content similarity dispersion	-0.0728***	-0.0787***	-0.0792***	-0.0855***	-0.0783***	-0.0843***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Field distance dispersion	-0.0372***	-0.0360***	-0.0510***	-0.0509***	-0.0492***	-0.0485***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Ratio of self-citations to total work cited	-0.0409***	-0.0475***	-0.0423***	-0.0486***	-0.0417***	-0.0482***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Mean age of work cited	0.0019***	0.0004***	0.0020***	0.0005***	0.0019***	0.0004***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Dispersion in age of work cited	-0.0037***	-0.0045***	-0.0037***	-0.0045***	-0.0037***	-0.0045***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Mean age of work cited × Dispersion in age of work cited	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Mean number of prior works produced by team members	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Year fixed effects	Yes	No	Yes	No	Yes	No
Field fixed effects	Yes	No	Yes	No	Yes	No
N	3420673	3420673	3420673	3420673	3420673	3420673
R2	0.12	0.10	0.11	0.10	0.12	0.10

Notes: This table evaluates the relationship between different measures of the use of prior technological knowledge and CD_5. Estimates are from ordinary-least-squares regressions. Each coefficient is tested against the null hypothesis of being equal to 0 using a two-sided t-test. We do not adjust for multiple hypothesis testing. Robust standard errors are shown in parentheses.
Standard errors in parentheses.
+ p<0.1; * p<0.05; ** p<0.01; *** p<0.001.

CONCLUSIONS

Conclusions

- Despite the decline in disruptiveness, inventors are increasingly acquiring knowledge from different fields.
- Exaptation can promote the disruptiveness of innovation, leading to ongoing disruptive growth.
- Inventors looking for big changes should learn from many fields to create unexpected breakthroughs.

Acknowledgements

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THANK YOU☺