Identification and Analysis of Technology Emergence Using Patent Classification

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Key findings

- A rapid increase in patent applications filed related to a specific classification can represent its dissemination into new and often unrelated technological areas. This rapid increase in patent application filing is a signal of technology emergence and industry acceptance.

- S-curves of patent applications and issued patents often appear when classifications and subclassifications form an increasing number of linkages to other classifications and subclassifications.

- Through analysis of the emergence s-curve, by categorizing patents in terms of their distance from the year of emergence, we define a potential value metric for technology transfer staff in government, nonprofit institutions, or private-sector firms seeking to maximize the value of their patent portfolios or their chances of winning in the event of litigation.

- The same analysis of the position of patents in time with respect to the year of emergence provides a means to analyze patent portfolios of individuals or organizations with respect to whether they are "leading" or "following" the commercial interest in the field.

- Comparison of the tendency of organizations to be "leading" or "following," in specific areas in which they patent provides a metric of the novelty of their work in those areas.

- Analysis of the spread of technology into new areas provides a means of identifying areas into which technologies may be most likely to move in the future.

SUMMARY ■ Technological advances can result in disruptive changes with social, economic, and political ramifications. Disruption causing worldwide paradigm shifts in the commercial sector has been long recognized and extensively studied.[1] Many researchers have analyzed bibliographic data related to technical papers and patents seeking to gain insight into emergent technologies.[2] With respect to patent literature specifically, many different methods have been used to analyze patent citations.[3] However, citations in patents serve a very different purpose than citations in academic publications, which are typically made to identify foundational literature or methods upon which the data, analysis, or methods in the manuscript are based. Citations in patents do not necessarily identify foundational patents; rather, they are made by patent attorneys and patent examiners to provide information about the most relevant art that will justify the acceptance or rejection of the patent. A recent analysis of patent citations demonstrates that the relationship between patent value and citations is nonlinear and not monotonic.[4] This report describes an alternative approach that uses the classification system developed by the United States Patent and Trademark Office (USPTO) to identify, analyze, and evaluate the emergence of technology into new areas. More specifically, we use the organically developed and continually updated USPTO classification system as a means of developing connections in the technology network and analyzing the patent landscapes around newly emergent technologies;[5] i.e., those that have shown a surge in patent activity in recent years. We illustrate this approach using two specific examples of emerging technologies: Global Positioning Systems (GPS), which emerged in the mid-1990s, and nanometer-scale semiconductors (commonly known as quantum dots), which only began their emergence within the last few years.

Our analysis of patent landscapes is aimed at understanding the magnitude and timing of the growth of commercial interest in specific technology areas. The magnitude provides an indicator of the level of commercial interest, while the timing provides an indicator of novelty by identifying whether specific patents are early (few patents filed in the technology area) or late (many patents already filed in the technology area) in the emergence. Our intention is to enable patenting organizations or sponsors of those organizations to evaluate their patent portfolios using these two indicators (magnitude and timing).

Patents as Bets

While the complete story of the value of a particular technology is not told by the number of patent applications filed in a year or the new measurable diffusion of the technology, clearly the level of industrial interest can be gleaned from these data. *Each filed patent application represents a bet by some entity that a particular technology will become economically important.* To develop the technology needed to file a patent application, organizations expend both engineering and legal time and capital. The desired payoff for this investment is monopolistic control of a section of the technology space, allowed by present law for 20 years from the filing date. We will show in this report how analysis of data on published patent applications and issued patents can indicate technology areas in which these "bets" are increasing rapidly as a signal of technological emergence.

The story behind new technologies is further developed closer to the time of issuance of a patent. This is because, within some limitations, applicants can change their "bets" by amending the claims of their application based on either the prior art cited by the patent examiner or economic realities surrounding the markets for products incorporating the claimed technology. At the time of issuance, typically four years after the application was filed, a commercial product may have been developed, the claims of the patents have been tuned and tested at the respective patent office, and market-driven

commercial realities may have changed.[6] Because of these factors, the claimed inventions in an issued patent will likely have been assigned classifications that more closely relate to the true nature of advancement in the application, as compared to those assigned when the patent application was published, which reflect earlier stage intentions. Accordingly, a rapid growth in published patent applications in a technical area can reflect not only a simple measure of institutional interest, but also a measurable movement of technical concepts between application areas, as we demonstrate below for nanoscale semiconductors (quantum dots).

USPTO Technology Classifications

Throughout the history of the United States, the USPTO has been monitoring and shepherding the growth of developments in technology. The patent examiner is critical to the machinery of the patent office. He or she is a professionally trained technical specialist who is charged with the evaluation of patent applications. Because of internal systems within the USPTO, the patent examiners behave in a predictable and regulated manner when categorizing technologies. To assist the patent examiner in finding the "best" relevant prior art to attack the claims of a patent application, the USPTO and patent offices around the world have developed highly sophisticated classification systems to categorize and characterize technologies. These systems have been around for more than a hundred years and have functioned to categorize technologies in an indexable manner. While the definitions of technologies vary by nation and have changed over time, the methodologies used have been relatively stable. Because the characterization of individual patents is performed with the objective of reducing the patent examiner's work in the future, there is self-incentive and pressure to get the categorization correct. There are also mechanisms within the USPTO to correct misclassified patents and patent applications.

The USPTO's formal categorization system has been used to classify literally millions of technical documents. The classifi-

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cation is not merely a single technical descriptor, but a categorization of all the areas of science and technology advanced in the document as recognized by the patent examiner. Consequently, the interaction of these classifications in the patent system provides an accurate representation of technologies' application and interaction over time. The joining of patents in one technological area with those in other technological areas occurs as a function of time when a technology has moved into a new, industrially important area. A rapid increase in patent applications filed related to a specific technology thus can represent its dissemination into new and often unrelated technological areas. This rapid increase in patent application filing is a signal of technology emergence and industry acceptance. We will show how time-dependent changes of these interactions in a technology domain network inform an epidemiological type of spread of technologies and, based on knowledge of past associated technologies, can be used to anticipate the flow of new technologies.

ANALYSIS OF PATENT CLASSIFICATION DATA

The USPTO classification system is divided into technological art areas, from animal husbandry to optoelectronics. These classifications, which are given alphanumeric labels, are then further subdivided, again using labels, into subclassifications. These subclassifications (subclasses) can be further subdivided to better define the technological areas. The "class, subclass" representation for a specific technology can be visualized as a set of trees. However, just as familial relationships do not describe interactions among humans, this type of classification system alone cannot describe the interactions among different technological areas.

While the USPTO uses classification systems to describe technologies, there is little formal guidance for the patent examiner regarding where to look for related technologies that may act as an anticipating reference. To expedite prosecution and improve the quality of applications, the patent examiners in various patent offices are often placed into groups that specialize in specific technologies. These groups work closely together to determine the likeliest place to find prior art. While searching for prior art is now often conducted using key words in addition to the classification system, practitioners realize that the search for the best prior art is, in itself, an art form.

> A rapid increase in patent applications filed related to a specific technology can represent its dissemination into new and often unrelated technological areas, which signals technology emergence and industry acceptance.

The Patent Office has provided a link between these classifications, however, which can be used to determine where and when related technologies might appear together. This linkage appears on the front page of issued patents and published applications themselves. In this regard, the front page of the patent presents not only the classifications of the invention as claimed by the applicant, but also where the examiner has searched for anticipatory references for the entire invention or any of its components.[7] These searches and classifications represent where the trained patent examiner believes there are past and contemporaneous linkages between technologies—his or her best judgment concerning technological relationships. We thus use these data to investigate potential flows of technology.

Characterization of the Patent Classification Network

Figure 1 is a network map of the classifications and associated interactions of technologies as defined by the USPTO for patent applications filed in 2010. The points in the figures, or nodes, represent top-level patent classifications. The lines connecting the points, or edges, represent linkages between different classifications, defined as the appearance of the two classifications on the front page of the same patent. The thickness of the lines, or weight of the edges, represents the number of linkages between the classifications, with thickness (weight) increasing as the number of linkages increases. Figure 1 was

Figure 1. Network of USPTO Classifications for Patent Applications Filed in 2010
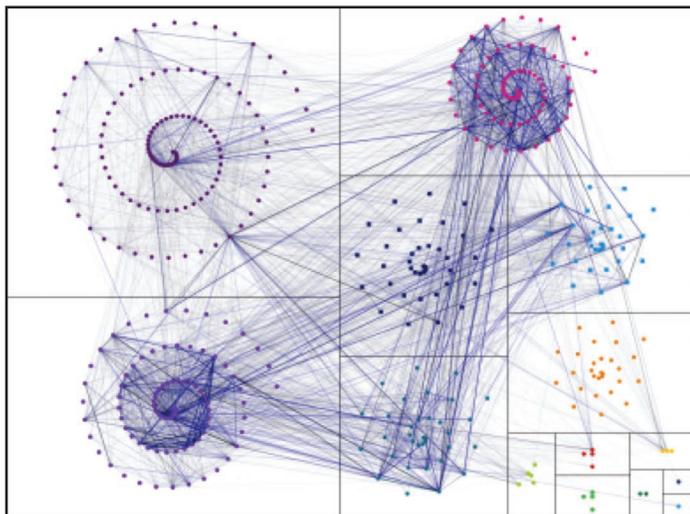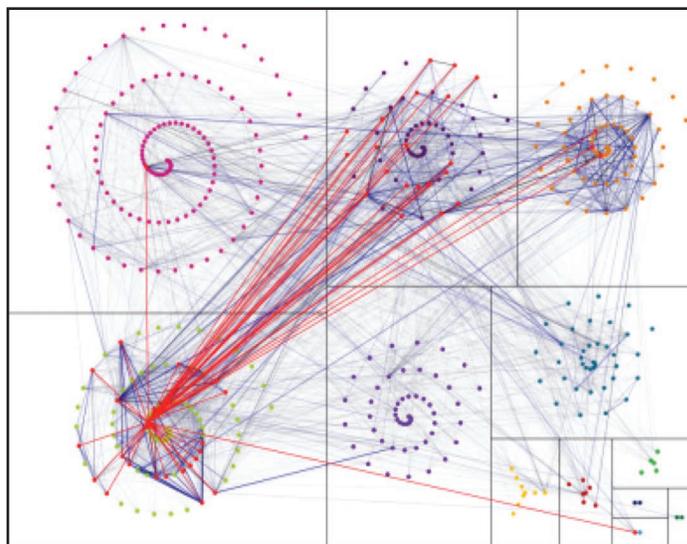

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developed using a hierarchical clustering method based on clustering networks having the highest similarity in the tree structures of their class and subclass representations, as categorized by the patent examiners. More specifically, the clusters shown in the figure were defined using the Wakita-Tsurumi method in NodeXl.[8] The nautilus structure of the figure is an artifact of the display method and has no special significance. The boxes provide a guide to the eye by separating clusters of classifications.

In many circumstances, the linkage between two classes in Figure 1 is very strong, as evidenced by a large number of patents referencing both classes and represented by heavily weighted edges in the figure. The darker lines in the figure thus represent as many as hundreds of linkages (interactions) between a pair of classes, while the light lines represent only a few. Cumulatively, thousands of pairs of classification linkages between two closely related fields may occur on the front page of patents. As an example, Class 128 for surgery and Class 623 for prosthesis have appeared together on the front page of patents more than 1,000 times since 1976. In other circumstances, classifications engage each other very rarely, and in still other cases, classifications are simply not related and do not engage each other at all. For example, since 1976, Class 449 for bee culture has never appeared on the front page of a patent together with Class 438 for semiconductor device manufacturing. Generally, these linkages are indicative of the co-applicability of a pair of technologies, change as a function of time, and represent the application of technologies into new areas.

As a specific example to illustrate the flow of technology within the patent classification network, we examine the area of nanotechnology, USPTO Classification 977. Figure 2 shows the linkages (interaction) of nanotechnology (node in the box in the lower lefthand corner, with all edges colored red) with other technology classifications in the year 2002. Figure 3 shows the time dependence between 2000 and 2011 for the number of patent filings in nanotechnology (left axis) and the number of other technology classifications to which nanotechnology is linked—or, in network terms, the degree of nanotechnology (right axis). Both show a large increase between 2000 and 2010, but in 2011 the number of filings in nanotechnology decreases from its 2010 value, while the number of linked classifications (degree) remains almost constant. Because of the 18-month delay in the publication of patent applications filed with the USPTO, data for 2012 are incomplete, so we cannot tell whether these trends will continue. Nevertheless, the data through 2011 suggest that patenting in nanotechnology may have reached its peak, and most of the other classifications that show most promise for nanotechnology applications (and thus linkages) have been identified. We note, however, that new linked classifications can appear in the future without an increase in degree, as long as other formerly linked classifications are no longer linked, and that it is common for linkages between classifications to appear and disappear in any given year.

Figure 2. Network of USPTO Classification 977, Nanotechnology, for Patent Applications Filed in 2002

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Figure 3. Number of Applications Filed and Other USPTO Classifications Linked to USPTO Classification 977, Nanotechnology, for Patent Applications Filed Between 2000 and 2011
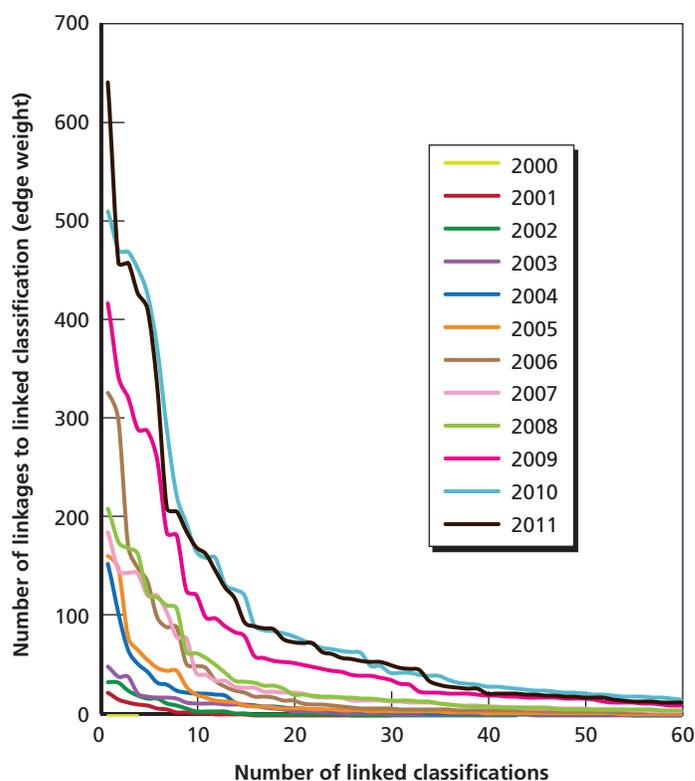

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Figure 4. Distribution of the Number of Linkages to Other USPTO Classifications of USPTO Classification 977, Nanotechnology, for Patent Applications Filed Between 2000 and 2011
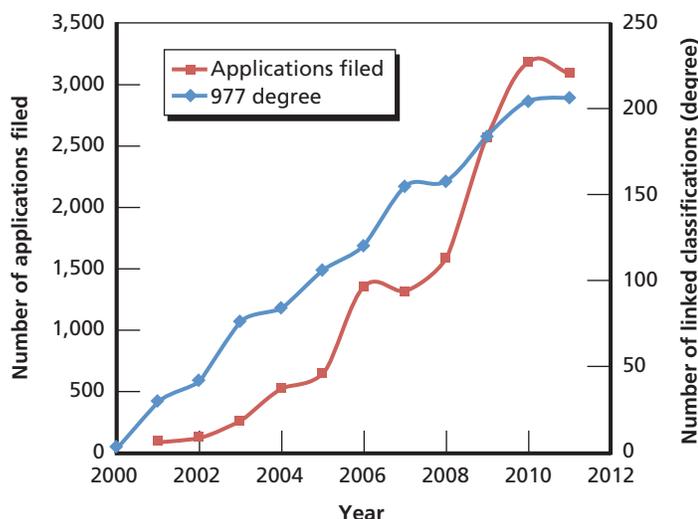
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Figure 4 shows the distribution of the number of linkages with nanotechnology (edge weight) for each linked technology classification as a function of time between 2000 and 2011. We make two observations about Figure 4. First, the distribution is strongly skewed—a very small number of classifications have many linkages, some have a moderate number of linkages, and there is a long tail formed by the many classifications with few linkages. This is typical of a network that shows preferential attachment,[9] which here means that once nanotechnology is shown to be useful in a technology area, nanotechnology patents are preferentially filed in that technology area. Second, the distribution maintains its shape and its maximum increases monotonically between 2000 and 2006. The shape is maintained for the rest of the observed time period, but the maximum decreases from 2006 to 2007, consistent with the decrease in nanotechnology patent filings between 2006 and 2007 (see Figure 3). After 2007, the maximum edge weight increases monotonically again, exceeding its 2006 value in 2009, and continuing to increase through 2011, indicating that the number of patents filed in the most active nanotechnology application areas was still on the rise in 2011, the latest year for which we have complete data.

In summary, an increase in the number of classifications (technologies) linked to nanotechnology is clearly evident from 2000 to 2011, with the number of linkages (which was shown as the darkness of the lines in Figure 2) to the most linked

classifications (technologies) still increasing. These linkages represent instances in which industry either has attempted to solve particular technical problems using or implementing nanotechnology or it has applied technology into the manufacture of nanoscale materials. They also represent, because patents were granted, new instances of the use of a technology to address a new nonobvious (to one skilled in the art) technical problem area. In this context, we note that the application of nanotechnology to solve problems in nonobvious technical areas represents *nonobvious improvements* to these areas. Changes in this signal can be used by industry and policymakers as an indication of technical importance. In fact, these now-mappable events have long been recognized by the USPTO and the courts as indicators of nonobviousness.[10] Classifications into which nanotechnology has moved between 2002 and 2011 include semiconductor devices, coherent wave generators, drugs, bioaffecting and body treating compositions, coating, and batteries.

S-Curves as an Indication of Technology Emergence

S-shaped, or logistic, curves are a widely recognized indicator of emergence of a variety of physical phenomena. For example, it was demonstrated recently that the emergence of many great engineering accomplishments of the 20th century can be represented by s-curves.[11] It thus comes as no surprise that s-curves of patent applications and issued patents often appear when classifications and subclassifications form an increasing number of linkages to other classes and subclasses. We use the example of Vehicle Navigation using Global Positioning Systems (GPS), Classification 701, Subclassification 213, (hereafter, we will use the notation 701/213 to indicate class/subclass) to illustrate this phenomenon. Figure 5 shows the cumulative number of patents issued by the USPTO in 701/213 per year from 1985 to 2010. The inset in the figure shows the concurrent growth of the network for GPS; i.e., the classifications to which it has linkages. The line below the x-axis shows an estimate of the error associated with the fit of the patent data to an s-curve using software developed by Loglet Laboratory.[12] Two observations are clear from this figure:

- While patents were issued in the late 1980s, it was not until the mid-1990s that rapid (exponential) growth occurred in the cumulative number of patents issued.
- This exponential growth in issued patents was associated with the linkage of GPS with an increasing number of other technical areas, which (as we know in hindsight) reflected the increasing use of GPS in more and more applications as the size and cost of GPS were reduced from thousands of dollars for a bulky device to a few dollars for a palm-sized component.

Today we find GPS in everything from ski goggles to tennis shoes. Figure 5 thus serves as an illustration of the correspondence between the s-curve representation of technology emergence and the growth of linkages between the technology classification and other classifications.

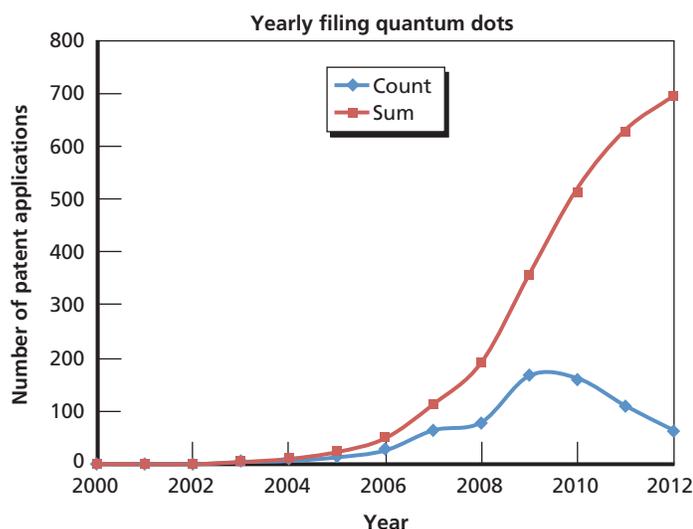## Figure 5. Cumulative Number of Issued Patents in Vehicle Navigation Using GPS

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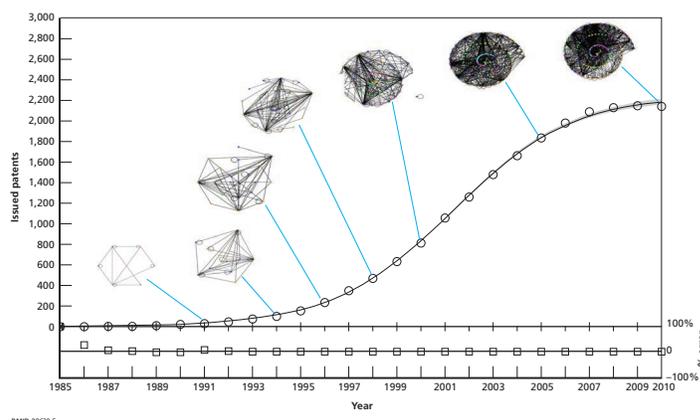
We now return to Classification 977, Nanotechnology, for which the growth of linkages to all other classifications were shown in Figures 3 and 4. In particular, we focus on a particular subclassification, 977/774, for quantum dots, which are nanoscale semiconductors that the USPTO defines as "a nanoparticle structure having three dimensions of 100 nm or less exhibiting three-dimensional carrier containment." Figures 6 and 7, respectively, show the s-curve for published patent applications on quantum dots, and the distribution of those applications into the class/subclass pairs into which they were classified by the patent examiner. Figure 6 shows an emergence beginning in 2005 with the sum of patent applications still increasing in 2011.[13] This emergence appeared 13 years after the filing of the basic foundational patent on quantum dots.[14] Thus, the curve effectively captures the time at which industrial interest in quantum dots began to rise rapidly. The interval between initial patents and this emergence of industrial "bets" will vary dramatically among technology areas; this examination of the s-curve provides a means to characterize technology emergence.

Figure 7 shows the spread of quantum dot technology into other technology areas, beginning with the 2005 emergence detected in Figure 6 and continuing through 2011. Figure 7 is a
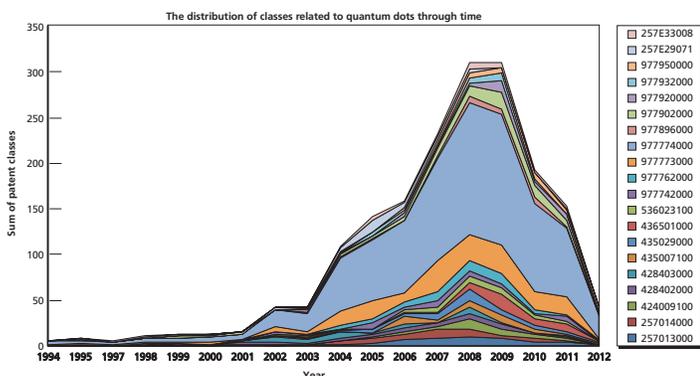
> S-curves of patent applications and issued patents often appear when classifications and subclassifications form an increasing number of linkages to other classes and subclasses.

Figure 6. Time Dependence of Published Patent Applications in USPTO Classification 977/774

Yearly filing quantum dots

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Figure 7. Number of Linkages to USPTO Classification 977/774 in Published Patent Applications Layered by Classification From 2000 to 2011

The distribution of classes related to quantum dots through time

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Table 1. Number of Linkages Over Time Between 977/774 and Other USPTO Classifications

	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Grand Total
257013000							1		1	2	3	7	8	10	9	4	4	1	50
257014000			2	1	1		1	2		1	3	6	6	10	9	2	5	1	52
424009100										1	1	3	3	11	7	3	3		32
428402000								2	2	1	3	2	4	4	6	6	2	1	33
428403000								2	6	4	6	2	4		6			1	32
435007100									1	2	1	9	4	8	9	4	2	1	41
435029000										1	4	2	6	12	5	4	3		38
436501000		1			1				1	1	1	2	2	8	17	8	8	1	51
536023100						1		2	1		3	5	6	8	4	3			33
977742000				1			2	1		1	7	3	7	6	4	1	5	1	39
977762000		1		1			1			3	4	5	10	12	12	5	2	1	57
977773000	1	1	1	1	1	2		6	3	16	19	10	34	28	31	19	20	2	195
977774000	4	3	3	4	5	6	6	18	21	59	67	79	112	145	143	97	75	25	872
977896000		1							1	1	1	1	3	7	5	7	2	2	31
977902000				2	1	2			2	3	4	9	11	19	12	6	1		72
977920000								2	2	1	4	3	2	12	5	7			38
977932000						1			2		4	3	1	6	9	3	1	1	31
977950000							1	1		1		3	4	6	5	7	4	6	38
257E29071		1		2	1			2		1	5	13	5	5	4		1	1	41
257E33008			1	1					1	1	3	2	3	7	6	3	3		31
Grand Total	5	8	5	11	12	12	16	42	43	109	141	159	233	310	311	193	153	44	1807

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to definitions and broad uses for quantum dots. These definitions include the use of quantum dots as a nanocomponent (977/902), Detection of biochemicals using quantum dots (977/920), or the definition of nanostructures having quantum confinement properties (977/762). The USPTO has also recognized inventions related to the use of quantum dots with carbon structures such as fullerenes or graphene (977/742).

In addition to recognizing quantum dots as being nanostructures, the USPTO also classifies quantum dots as being related to semiconductor devices. In this regard, 977/400 was cross-assigned with active semiconductor device classifications; e.g., heterojunction devices having quantum wells (257/014), semiconductor quantum box or quantum dot structures (257/E29.071), quantum or nanowire (977/762).

Applications directed to the specific use of technologies are beginning to appear, and these are exactly the technical areas of the earlier linkages of nanotechnology patents. These include, for example, the use of quantum dots as incoherent light emitters (435/029). In the medical technologies area, quantum dots are beginning to appear in compositions of drugs and bioaffecting and body-treating compositions (424/009.1). Additionally, they are being used for in vivo diagnosis or in vivo testing (428/402) and a specific binding protein assay or specific ligand-receptor binding assay (435/007.1 and 436/501).

It has been proposed that when viewing the flow of information through a network, edge weights (shown in Figure 4 and represented by the matrix elements in Table 1) can be used to predict the likely flow of information.[15] The reasoning here is that, all else being equal, information is most likely to flow where it has the most available pathways. Similarly, we propose that the interactions between patent classes be used as a weighted network representing the interactions between tech-

"sand chart," in which each layer in the figure shows the number of published applications in a different class/subclass that are linked on the front page of their patents to 977/774. Table 1 lists these class/subclasses and shows the time dependence of the number of linkages to 977/774 for the most frequently linked of these class/subclass pairs. As with previous figures, because patent applications are not published until 18 months after they are filed, data in Table 1 are complete through 2011.

The richness of this spread is illustrated by the most prevalent technical areas in Table 1, which are areas previously linked to nanotechnology. While there is a continuum of uses identified by inventors, first applications were generally related

nologies. In this view, the strength of these interactions represents the likelihood that a newly developed technology from one area will flow into another, related area. We also observe that technologies recognized by industry as being applicable solutions to problems in one technological area are frequently applied to address important issues in a different area. Thus, inventions related to such technologies may be applied to solve the same known problems in the future. For example, nanotechnologies have been determined by the community at large to be useful to solve problems in medicine, medical devices, and electronics. Following the network logic described above, we propose that applications of quantum dots, a subclassification of nanotechnology, will likely continue to spread into these same areas.

We pursue this line of thinking by noting that, in some instances, the weight of an edge between a pair of classifications represents the tendency of advances in one technology area to flow into another. Thus, we envision that a new breakthrough or development in a single classification area will first flow into areas whose linkages to this particular classification area have strong weights. With respect to quantum dots, we evaluated the edge weights for classifications associated with the parent classification 977, nanotechnology. Quantum dots were originally associated with nanotechnology and active semiconductor materials. Quantum dot patents are now being filed in the diverse areas of coherent wave generators, drugs, bioaffecting and body-treatment compositions, coating, and batteries—all areas previously associated with the broad class of nanotechnology. Quantum dots, to date, have generally been applied to only a subset of these classes associated with nanotechnology. Since the s-curve in Figure 6 is not yet saturated, only time will tell if quantum dots will be applied to technical problems in the other classifications previously linked to its parent, nanotechnology.

CONCLUSIONS

In this report, we have described an approach and a method for identifying, characterizing, and analyzing the emergence of technologies into new areas, based on analysis of the assignments by patent examiners of published patent applications and issued patents to specific classifications and subclassifications within the USPTO classification system. We have shown how the linkages between these assignments, evidenced as co-assignments on the front page of the application or patent, form a network that represents the connections between, and movements of, technologies. We also showed that such emergence is accompanied by and is an indicator of the spread of the technology into new areas of the network of USPTO classifications. Finally, using the example of USPTO classification 977 (nanotechnology) and its subclassification 774 (quantum dots), we showed how the spread of the classification (or genus, borrowing a concept from biology) may mirror the spread of its subclassification (or species), thus informing where the species technology might move in the future. We also noted how this is consistent with current network theory.

The methods described in this report can be used by patenting organizations and their sponsors to evaluate their patent portfolios in two distinct ways. First, by placing their patent portfolios on s-curves, a patenting organization or sponsor can learn the level of interest in the broader patenting community in the technology areas in which the organization (and its staff) are patenting based on the s-curve's magnitude and duration. Second, the position of their patents on corresponding s-curves provides an indication of how early or late their specific patents are with respect to when the technology area first emerged. The former is potentially a measure of value; the latter is a measure of novelty, as it indicates how many other patents have already been filed in the area.[16]

Analysis of s-curves in technology classifications and subclassifications can thus provide quantitative support for the

Based on an s-curve's magnitude and duration, a patenting organization or sponsor can learn the level of interest in the broader patenting community in the technology areas in which the organization is patenting.

management of patent portfolios, as well as to guide research and development investment decisions.

Technology transfer staff in government, nonprofit institutions, or private-sector firms seeking to maximize the value of their patent portfolios or their chances of winning in the event of litigation can develop maps of their patents in different technical areas and compare these with existing and emerging s-curves in these and related areas, both with respect to the distance from year of emergence and the magnitude of the s-curves. This will allow evaluation of whether individuals and research groups are consistently "leading" or "following" in technical areas of high commercial interest. This analysis can be repeated at intervals or done continuously to provide an indication of the variation of novel activity over time.

The methods described in this report can also serve as a means to provide information about the potential likelihood of technology movements, along the lines shown in the quantum dot example.

Notes

[1] For example, see the description of "creative destruction" by Joseph A. Schumpeter, *Capitalism, Socialism and Democracy,* New York: Harper, 1975 (original publication 1942), pp. 82–85.

[2] See, for example, Christopher King and David A. Pendelbury, *Research Fronts 2013,* Thomson Reuters, April 2013. As of February 3, 2014: http://img.en25.com/Web/ThomsonReutersScience/1002571.pdf

[3] See, for example, Holger Ernst, "Patent Information for Strategic Technology Management," *World Patent Information,* Vol. 25, No. 3, 2003, pp. 233–242; Y. H. Chen et al., "Technology Forecasting of New Clean Energy: The Example of Hydrogen Energy and Fuel Cell," *African Journal of Business Management,* Vol. 4, No. 7, 2010, pp. 1372–1380; Deborah Strumsky et al., *Using Patent Technology Codes to Study Technology Change,* Santa Fe Institute, October 2010. As of April 25, 2013: http://www.santafe.edu/media/workingpapers/10-11-028.pdf and references contained therein.

[4] David S. Abrams, Ufuk Akcigit, and Jillian Popadak, *Understanding the Link Between Patent Value and Citations: Creative Destruction or Defensive Disruption?* University of Pennsylvania, 2013. As of May 23, 2014: http://www.kentlaw.iit.edu/Documents/Academic%20Programs/Intellectual%20Property/PatCon3/abrams.pdf

[5] The use of co-classified patents to develop a technology network based on the 2006 international patent filings and the classification system of the World Intellectual Property Office (WIPO) is also described in Loet Leydesdorff, "Patent Classifications as Indicators of Intellectual Organization," *Journal of the American Society for Information Science and Technology* (forthcoming). As of May 28, 2014: http://www.leydesdorff.net/wipo06/paper/index.htm

[6] A U.S. patent application is published, and thus openly available, 18 months after its filing. The decision to award a patent occurs later, often much later, typically 48 months after the filing of the application.

[7] While closely related, it is beyond the scope of this writing to discuss how the patent examiner combines references and what he or she regards as obvious.

[8] Ken Wakita and Toshiyuki Tsurumi, "Finding Community Structure in Mega-Scale Social Networks," Proceedings of the 16th international conference on World Wide Web Pages, ACM, New York, 2007.

[9] See, for example, Albert-László Barabási and Albert Réka, "Emergence of Scaling in Random Networks," *Science,* Vol. 286, No. 5439, October 15, 1999, pp. 509–512.

[10] *The Manual of Patent Examination Procedure,* U.S. Department of Commerce, United States Patent Office, Sections 1504.03, 2141(a), 2145, August 2007; and *Graham et al. v John Deere Co. of Kansas City et al.,* 383 U.S. 1, 1966.

[11] See Steve Wunderlich and Tarek Khalil, "Introducing Technology Timeline Interpretation to Technology Diffusion and Maturity Analysis as Applied to Different Industrial Sectors," University of Miami, 2004. As of May 29, 2014: http://tuvalu.santafe.edu/~bn/reading_group/Wunderlich_Khalil.pdf

[12] Perrin S. Meyer, Jason W. Yung, and Jesse H. Ausubel, "A Primer on Logistic Growth and Substitution: The Mathematics of the Loglet Lab Software," *Technological Forecasting and Social Change,* Vol. 61, No. 3, 1999, pp. 247–271. As of May 29, 2014: http://phe.rockefeller.edu/LogletLab/logletlab.pdf

[13] As with Figures 3 and 4, complete data were only available to 2011 because of the 18-month delay in the publication of patent applications filed with the USPTO.

[14] John Randall et al., "Method of Fabricating Shannon Cell Circuits," U.S. Patent Application 07/979, issued as U.S. Patent No. 5,346,851, filed November 20, 1992, assigned to Texas Instruments.

[15] M. E. J. Newman, *Networks: An Introduction,* Oxford, UK: Oxford University Press, 2010, Ch. 17.

[16] Potentially a measure of value because one does not know which of the many patent "bets" will turn out to be valuable. However, analysis of litigation payouts shows that patents early on s-curves are much more likely to provide payouts in litigation (RAND analysis, unpublished), so the measure of novelty is critical.

About the Authors

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About This Report

This report describes a new method for studying the emergence of technologies through the analysis of the relationships between patent applications and issued patents and their assigned classifications and subclassifications, which represents the network of connections between different technology areas. These classifications have been defined by the United States Patent and Trademark Office (USPTO) and patent organizations in other countries and regions.

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