VALUENEX
intellectual innovator

QUICK REPORT

TECHNOLOGY TREND ANALYSIS

An Analysis of Unique Patents for Utilizing Prime Numbers in Industrial Applications

Distributed March 9, 2016

At the start of 2016, news of the discovery of the largest prime number ever—approximately 22.33 million digits—spread throughout the world. In Japan in 2015, a prime number ruler was sold at a national university's co-op, and despite its impracticality, it was rumored to have sold quite well. Although there is a one-million-dollar prize for proof of the Riemann hypothesis related to prime numbers, it has remained unsolved for over 150 years, continuing to hold the world's attention.

This field has few practical applications, even within mathematics, and it gives the impression of being irrelevant to industrial applications. Regardless, it has managed to capture great interest around the world. Could prime numbers possibly be somehow useful to the world, given all the attention they receive? We know of only one use for the factorization of prime numbers: Internet security encryption. However, this application takes advantage of the fact that prime numbers are difficult to calculate, and it cannot be said that this is constructively useful. We surveyed inventions that use prime numbers from the world of patents to find examples, other than encryption, in how the numbers are used. For the analysis, we used Valuenex's proprietary tool for panoramic analyses using the text mining application TechRadar, and analyzed unexamined patent applications from the US.

Survey Population

The patents subject to this analysis are unexamined patent applications that had the phrase "prime number" in the name of the invention, its summary, or its claims, and that were published in the US from March 2001 to January 2016. The number of hits was roughly 1,000 patents, which is a tiny sample of the approximately four million patent applications made in the US per year. Since 2001, the number of patents has remained nearly fixed or only increased slightly, indicating that inventions using prime numbers are regularly being made (Figure 1).

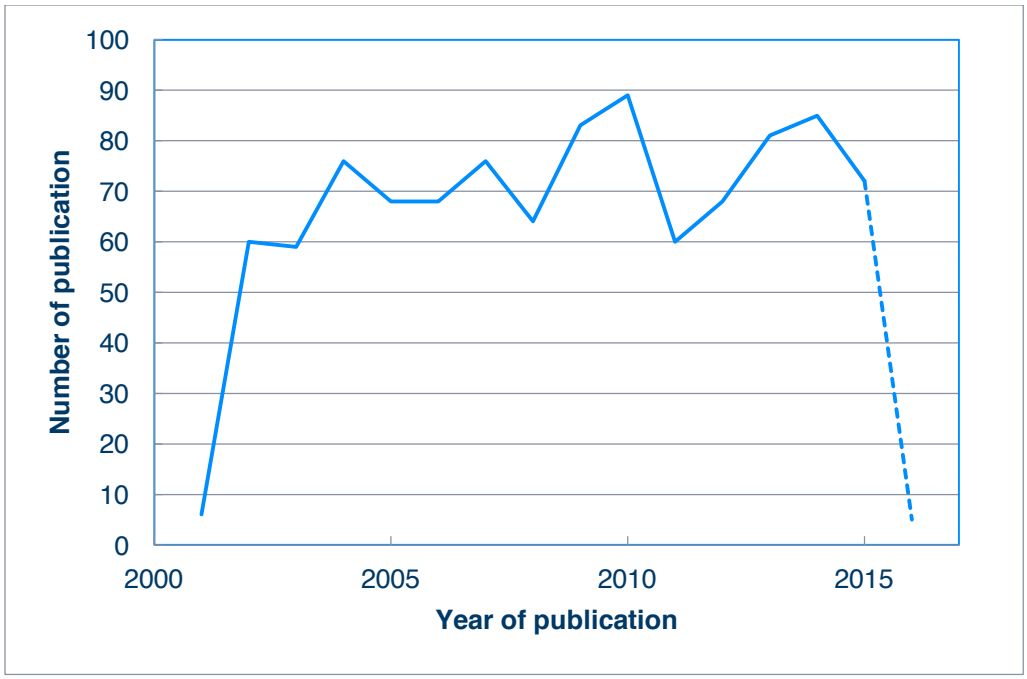

Figure 1 - Number of U.S. patent publication on prime numbers

Panoramic Analysis using Text Mining

We performed a panoramic analysis through text mining with XLUS TechRadar on the approximately 1,000 publications we uncovered. TechRadar automatically plots a massive number of similar patent applications according to the degree of shared similarities among them. It aggregates data from each of the primary publications to create multiple technology master templates. These templates allow the software to automatically classify the prime number technologies patented in the US and then to determine the level of similarity among them. Patented technologies using prime numbers were broadly grouped into three categories: encryption using prime numbers, error detection and correction using prime numbers, and actuator optimization and noise reduction using changes in prime numbers. These categories are indicated on the chart by the yellow-green ovals. They are further divided into several technology regions (indicated by red ovals on the Figure 2).

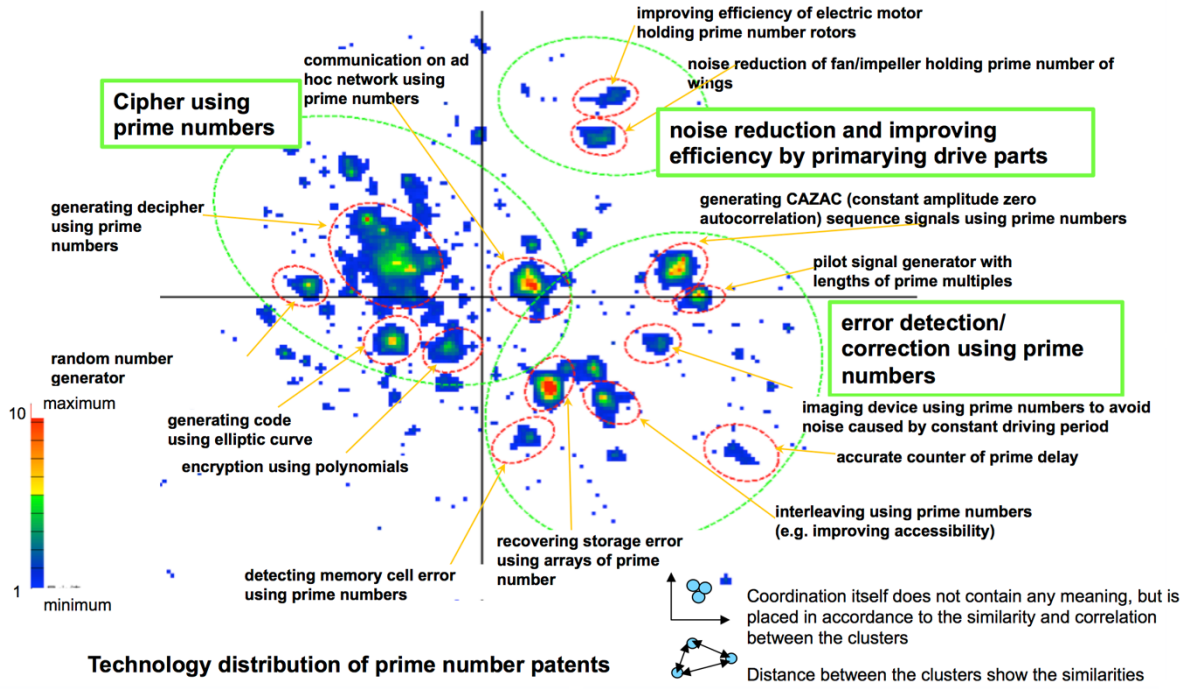

Figure 2 – Technology Distribution of Prime Number Patents

As expected, the largest patent group using prime numbers is encryption, and this group is further divided into regions according to the various types of encryption. Among those regions, the highest density is found in transmissions using prime numbers in ad-hoc networks. This region is in the center of the panoramic chart, making it literally the central invention among those that use prime numbers. A portion of this region is also included in the adjacent group; error detection and correction using prime numbers, meaning such inventions are used in both technologies. This second largest group—error detection and correction using prime numbers—is divided into the following technology regions: imaging devices that use prime numbers to prevent noise due to uniform drive cycles, accurate counters and similar devices with prime number delays, and interleaves that use prime numbers. These technologies constructively use the natural characteristics of prime numbers, unlike encryption, which takes advantage of the difficulty in calculating prime numbers.

The third group, actuator optimization and noise reduction using changes in prime numbers, has two technology regions: fan impeller noise reduction that uses numbers of blades equal to prime numbers, and improving efficiency in electric motors, with the number of rotors equal to prime numbers. These technologies also make use of the characteristics of prime numbers, and they use properties such as when the number of teeth for two gears are both equal to prime numbers, the oscillation period lengthens due to gear misalignment, which is caused by a reduced probability that the teeth specific to each gear will mesh. It is the same principle by which prime number cicadas (the larva of which spend a prime number of years underground) have a lower probability of

encountering their natural predators due to prime numbers being indivisible by other numbers.

Looking at the annual trends, patents in the group for encryption using prime numbers, shown on the left side of the panoramic chart, were greater in number in the early half of the 2000s. However, there has been a shift in applications to the right-side group of error detection and correction using prime numbers in recent years. It appears that patent applications are shifting toward the constructive use of the characteristics of prime numbers.

Key Organizations Committed to Technology

Reading the list of leading companies with unexamined patent applications related to prime numbers in the US shows a succession of leading electronics companies from the US, Japan, and South Korea (Figure 3). In particular, the top two positions hold the most patent applications. From third place on, the number of patent applications gradually declines.

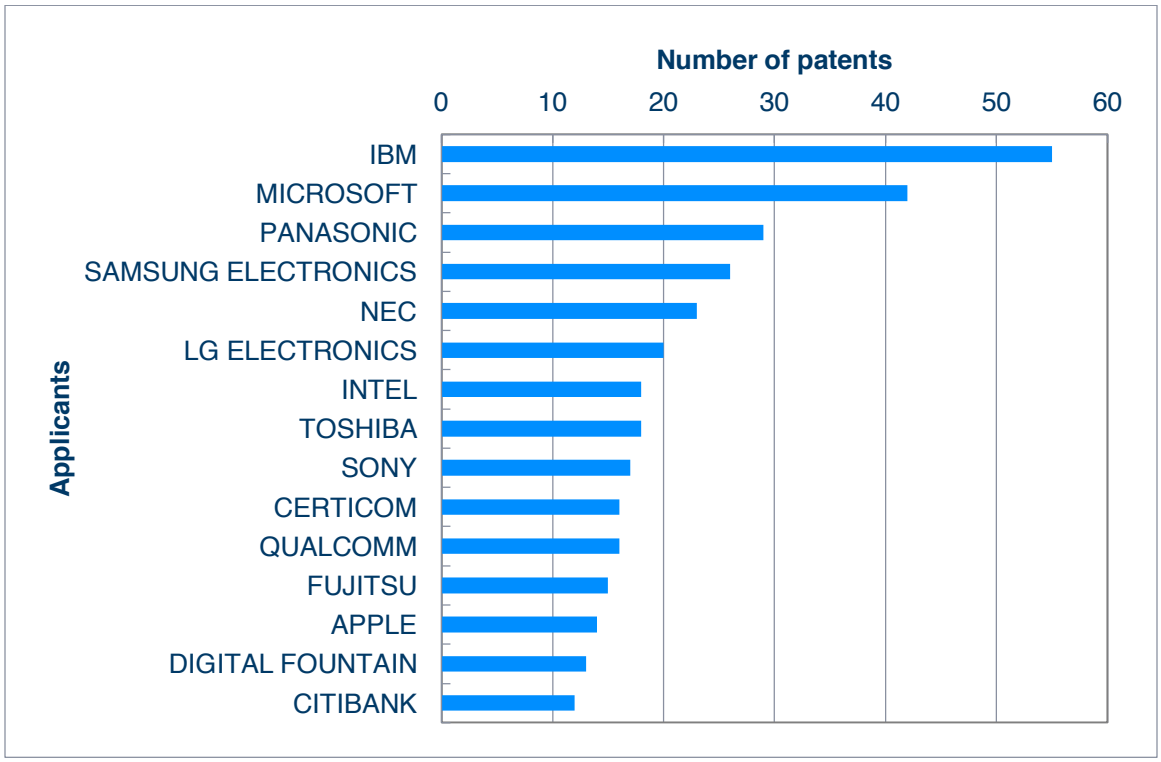

Figure 3 - Top 15 U.S. Patent publication on prime numbers

The leader – IBM (unlisted in Japan), and second-place Microsoft (unlisted in Japan) are both IT companies and both focus on technologies in the left-side group of encryption using prime numbers. However, IBM also concentrates the most on the ad-hoc network region of the chart, so it partially uses the characteristics of prime numbers

constructively. Conversely, household electronics manufacturer Panasonic Corporation (TYO: 6752) takes third place, with its focus on the region on the right side of the panoramic chart. The company's efforts are most notable in the regions for generating constant amplitude zero autocorrelation waveform (CAZAC) signals using prime numbers and storage error recovery using prime number arrays. Fourth-place Samsung (unlisted in Japan) is an unusual company that focuses on both left and right technology regions, while those firms in fifth and sixth places, NEC (TYO: 6701) and LG Electronics (unlisted in Japan), both have many of their applications on the right side of the chart. NEC, in particular, concentrates on the regions for storage error recovery using prime number arrays, while LG focuses on generating CAZAC signals using prime numbers. These two regions overlap with Panasonic's focus, meaning that these are the main technologies using prime numbers in which leading companies focus their efforts.

Conclusion

We performed a panoramic analysis of patent clusters using text mining to see trends in technologies using prime numbers in the US. Overall, there is a continuing shift from encryption using prime numbers, which takes advantage of the difficulty of calculations involving prime numbers, to error detection and correction using prime numbers, which makes constructive use of the characteristics of prime numbers. Branching from our initial inquiry, it appears that there are methods of using prime numbers outside of just encryption. Within the group for error detection and correction using prime numbers, the most notable regions are for generating constant amplitude zero autocorrelation waveform (CAZAC) signals using prime numbers, and storage error recovery using prime number arrays. The group for encryption has many applications from IBM and Microsoft, both US enterprises, while many of the applications in the region for error detection and correction using prime numbers are from Japanese and South Korean electronics manufacturers.

Prime numbers are characterized by their indivisibility by other numbers or, to put it another way, by the fact that numbers other than prime numbers are represented by combinations of prime numbers, which are essential values. To use a somewhat bold turn of phrase, the inventions that use these essential values are superior to those that do not, which is why the number of these types of applications are actually increasing. In the near future, we expect to see an even greater increase in inventions using prime numbers, thanks to a greater understanding of their characteristics, aided by factors such as the search for proof of the Riemann hypothesis.

VALUENEX INC
Customer Solutions Division

Tel: +1 650 319 8015
Email: customer@valuenex.com
www.valuenex.net

DISCLAIMER

This report was created with the intent of providing information, and is not intended to encourage investment or any other actions. Any final decisions regarding securities or other types of transactions should be made using the discretion and judgment of each individual. As an information source, VALUENEX Japan Inc. provides this report as trustworthy information. However, the company does not accept any responsibility whatsoever for any direct, indirect, incidental, special, or any other types of losses incurred, or possibly incurred, by anyone due to errors, omissions, and the like found within the report, or due to investments or other actions taken using the information found herein. Investigating and confirming the accuracy and trustworthiness of this report are not obligations of VALUENEX Japan Inc. The information contained in this report may be updated at the discretion of VALUENEX Japan Inc. All rights related to this report belong to VALUENEX Japan Inc.