Tackling Innovation Networks with Smart Data: A Case Study of the Liquid Crystal Institute at Kent State University

Hongshan Li
hli@kent.edu
Kent State University, United States of America

Marcia Zeng
mzeng@kent.edu
Kent State University, United States of America

Yin Zhang
yzhang4@kent.edu
Kent State University, United States of America

Xinyue Ye
xinyue.ye@gmail.com
Kent State University, United States of America

Tao Hu
taohu07@hotmail.com
Kent State University, United States of America

Numerous innovations and inventions have been made by human beings in the past few millennia, providing the most important driving force for economic, social, and cultural developments. However, for thousands of years, credits for most of these innovations and inventions have been given to individual genius-inventors in almost all civilizations. While the Chinese credited the Yellow Emperor for the invention of the compass and Cai Lun for papermaking, the British and the Americans honored James Watts and Wright Brothers for the invention of the steam engine and aviation respectively. This genius-inventor approach dominated the history of innovation for centuries, partly because it was difficult, if not impossible, for both professional and amateur historians to access or process information beyond a limited number of individuals involved in those creative activities.

The predominant position of the genius-inventor approach has been challenged when computers and other technologies invented in recent decades drastically increased human capability in acquiring and processing large amounts of data. By taking advantage of these new innovations, some scholars began to reexamine various major innovations by expanding their scope to cover the complex interactions between genius-inventors and their peers. With this new approach, F. C. Moon discovered that many of those innovations were actually the products of extensive interactions between the well-recognized geniuses and large social networks around them. While shedding new light on many of the innovations done in the industrial age or earlier, this new genius-centered network paradigm still pays the most attention to the central role played by the genius-inventors. This tendency limits the paradigm's ability to explain the numerous innovations and inventions made in the past century or so that did not involve any well-recognized individual geniuses. The invention of the liquid crystal display is one of those cases. Widely used in making TVs, computers, stationary and mobile phones, various control panels, billboards, watches, clocks, microwaves, and many other products that affect every aspect of our daily lives, the liquid crystal display was invented and improved by a large number of researchers who worked closely with their collaborators along the way. This absence of a single "genius inventor" in the development of the liquid crystal display and many other innovations calls for a new approach, one that will focus squarely on the large number of researchers who formed various networks that made those inventions possible.

This paper approaches the invention of liquid crystal display from a new perspective. Instead of focusing on genius-inventors or genius-inventor centered networks, this study examines all the researchers at Liquid Crystal Institute at Kent State University (LCIKSU) as nodes in an institutionalized network, and explores their interactions among themselves as well as with outside collaborators. LCIKSU is chosen not only because it is the largest research institute in the field that has made unparalleled and sustained contributions to the invention of liquid crystal display, but also because it has kept comprehensive institutional records since its inception, which makes it relatively easy to trace and analyze the growth and adaptation of this unique network of researchers.

The examination of LCIKSU is based on extensive data drawn from various sources. The research group, whose members come from the disciplines of Library and Information Science, History, and Geography, has

been given the access to all the available institutional records, including the LCIKSU annual reports, grant and patent applications, conference and exchange information, etc. All living directors of LCIKSU, incumbent as well as retired, have given long interviews, some meeting with the group multiple times. In addition, a large amount of data has been collected from various other sources such as the number of LCIKSU researchers' publications from Web of Science, their grant awards from the National Science Foundation website, and their patent awards from ProQuest. With the help of various available data processing tools, usable information has been extracted from all these historical records and turned into smart data, which is then used to accurately measure the contributions made by LCIKSU to the invention of the liquid crystal display, and to decipher the secret of its success as a complex network of researchers.

The careful study of the LCIKSU history reveals that the success achieved in the invention of liquid crystal display in the past fifty years has depended on the establishment and maintenance of a dynamic and productive network of researchers who collaborated closely with each other both within and beyond their own subfields or disciplines. Instead of looking for a genius inventor or becoming one themselves, the LCIKSU directors made every effort to recruit collaborating scientists to cover various sub-fields related with liquid crystal research. Some of the scientists, between a handful to a dozen over time, emerged as primary nodes in the network, producing the most paper publications, winning the most grants, and receiving the most patents. Usually leaders in their own subfields, these primary nodes not only worked with each other in conducting cutting-edge research, but also built their own sub-networks through various means and extended collaboration with other scientists throughout the university system, across the nation, and around the world. In order to better understand and illustrate the success of the LCIKSU researchers, the smart data collected on their papers published, grants received, and patents awarded is processed using various network analysis tools so that the degree and frequency of their collaboration can be measured and analyzed. The resulting assortativity, average clustering coefficient, degree centrality, closeness centrality, and between centrality indicators fully support the assessments made by individual researchers that the concentration of a large number of scientists, especially the primary nodes, at LCIKSU and the close collaboration among them have made it possible for these networked scientists to produce more and better research results at greater speed. After all, it is this sustained high level of research that has made LCIKSU the lead inventor of the liquid crystal display.

Joseph Schumpeter, one of the best-known economists in the 20th century, accurately observed in the early 1940s that technological progress was increasingly becoming the business of teams of trained specialists. However, team innovators who have played a growing role in innovation and invention have not received adequate attention. This examination of LCIKSU not only puts the researchers and their networks in the spotlight of the invention of the liquid crystal display, but also introduces a new approach that sharply focuses on the networks of scientists and extensively uses smart data. With further development and refinement, this new network-centered and smart-data-based approach has the potential to help narrow the existing gap in the study of modern history of innovation.

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