Exploring Technology Evolution Using Patent Classification: A Case of Cochlear Implant Technology Patents

Srigowtham Arunagiri, Mary Mathew
Department of Management Studies, Indian Institute of Science, Bangalore, India

Abstract--**Understanding technology evolution through periodic landscaping is an important stage of strategic planning in R&D Management. In fields like that of healthcare, where the initial R&D investment is huge and good medical product serve patients better, these activities become crucial. Approximately five percentage of the world population has hearing disabilities. Current hearing aid products meet less than ten percent of the global needs. Patent data and classifications on cochlear implants from 1977-2010, show the landscapes and evolution in the area of such implant. We attempt to highlight emergence and disappearance of patent classes over period of time showing variations in cochlear implant technologies. A network analysis technique is used to explore and capture technology evolution in patent classes showing what emerged or disappeared over time. Dominant classes are identified. The sporadic influence of university research in cochlear implants is also discussed.**

I. INTRODUCTION

The unceasing need for better life provides an impetus for industries, universities and governments to constantly invest in R&D activities and provide innovative solutions for addressing unmet needs or redressing existing solutions in a better way with the help of technologies. The recent times are characterized by shortening life cycle of technologies, availability of multiple complementary technologies and higher R&D costs, thus, it becomes really essential to understand and capture the evolving nature of technologies to preserve the competitive advantage in the market. Alongside evolution, activities such as technology forecasting, evolving the technology trajectory, road mapping for future and life cycle management, help industries make better strategic decisions for R&D [6]

The medical device industry is a crucial research-intensive industry, striving to meet indispensable needs of humans, such as, better health. Medical device industry spends 9-11 percent of their sales income in R&D activities, second only to the R&D investments of pharmaceutical industries. With the life cycle of a new medical device being eighteen months, it is required that medical device companies stay abreast with prevalent technologies and their evolution [3] This paper focuses on technologies related to implant devices, namely cochlear implant devices, which help in restoring hearing to patients whose inner ear is dysfunctional. With almost 5 percent of the world population suffering from hearing impairments and hardly 10 percent of the needs being met [20], there is a scope for extensive future R&D in technologies addressing hearing impairment. Since cochlear implant devices are built on innovative concepts from various disciplines like materials research, communication systems, physics, biology, electronics and design, it becomes a challenging device group to understand the evolution of technologies.

This paper is organized as follows: section II provides a review of literature related to concepts of technology evolution and current approaches to capture technology evolution. Section III elaborates on the data, sample and an outline of framework to capture technology evolution and subsequent analyses. Section IV summarizes the results of analysis and Section V concludes the paper.

II. LITERATURE REVIEW

A. Defining technology evolution

Evolution literally denotes a process involving gradual and continuous changes accumulating over a period time in response to one or more stimuli from the surrounding environment. Many scholars attempt to define and explain technology evolution from various perspectives. Recently, Lee et al. [11] attempts to define technology evolution in terms of technology innovation. Authors define technological innovations as the process facilitating the progress of technology through R&D and long term accumulation of these technological innovations are defined as technological evolution. This definition resulted from the synthesis of concepts and definitions from Schumpeter [18], Christensen [7] and Nelson et al [16] Schumpeter [18] defines technological evolution as “creational destruction process”, characterized by the constant modification of existing technologies by choosing concepts from various alternative technologies, as the technological innovation progresses and accumulates over time. More generically, Nelson et al. [16] defines technological evolution as accumulation of technological innovations. Later, Christensen [7] attempts to define technological evolution as a process involving diffusion and modifications of technologies resulting in development of one or a group of technologies. Additionally, the works of Saviotti [17] and Adomavicius et al. [1] defines technology evolution as change in technology over time, considering the development of novel technologies and enhancement of prevailing technologies. Authors emphasize that technology evolution cannot be understood by observing a single technology and its trajectory in isolation. Instead it is better to consider a group or system of interrelated and interdependent technologies to gain better insights on technology evolutions. Moreover, Saviotti [17] enumerates birth, death, incremental, transfer and diffusion of a technology and emergence of new technologies as five patterns in which technology evolutions occur.

B. Patent information: A tool for technology evolution

Patents and scientific publications are considered rich source of knowledge, since they are direct outputs of research activities. Yoon et al. [21] affirms that patents being an abundant source of technical and economic information become indispensable for high-technology management. Han et al. [8] explains that patents are a measure of direct outcome of research, and provides information on intensity and also direction of R&D activities. Liu et al. [13] claims that a group of patents in addition to representing accumulated knowledge gives insights on technology trajectory, life cycle, technology maturity and other characteristics. While Liu et al. [13] uses growth in number of patents to ascertain technology life cycle, works like that of Yoon et al. [21] and Chen et al. [6] use patent citation data for capturing technology life cycle. Lee et al. [10] adds that patents can be considered a good proxy for measuring or capturing any technology. Recently, Lee et al. [11] adds that patents can be used to observe emerging and disappearing technologies, which are salient features of technology evolution. Moreover, growth in number of patents awarded was used to capture the technology growth trajectory, an aspect of technology evolution [13] Lee et al. [10] also attempts to forecast technology evolution by considering the growth patterns of a cluster of similar patents. Nam et al. [15] attempts to capture global technology trends using network analysis of individual country's patent counts. Mowery et al. [14] uses patent data to understand the research focus of universities and corporates, where they assert that university research has profound influence on industrial R&D paradigms only in biomedical industry rather than other industries, which show sporadic university influences. Works of Su et al. [19], Lee et al. [12], Chen et al., [4], Chen et al. [6] and Lee et al. [11] use patent citations to capture technology evolution. However, this method is vulnerable to some drawback as enumerated by Yoon et al. [21] Since citations establish connections between two patents, the cited and citing patents and dependent on age of patent, understanding the overall relationship between patents gets tougher with citation analysis. Other drawbacks are limitation of valuable information and scope of analysis, misleading interpretations while considering only presence or absence of citations and consumption of more time [21, 9] Han et al. [8] augments that citations are given both by applicants and examiners, which may actually inflate the actual knowledge spillovers between the citing and cited patents. Alternative approaches are suggested by Yoon et al. [21], Chang et al. [2], and Yoon et al. [22] who use information derived from the patent title, abstract and claims to capture technology evolution. Their approach primarily focuses on clustering of related patents based on co-occurrence of keywords, which explain novel aspects of the patents. Surprisingly, literature involving usage of patent classifications for capturing technology evolution is scarce. Lee et al. [11] used number of patents filed and citation data for specific technology classes and captures evolution using indices. Our paper focuses on using patent classifications for capturing the changes in R&D intensity of various interconnected technologies over time and hence visualizing the technology evolution.

C. Technology evolution: Current approaches

Predominant approaches employed for capturing technology evolution are based on bibliometric analysis of patent documents using text mining techniques, either keyword or citation-based approaches [19] Su et al. [19] and Lee et al. [12] used patent citation data to construct a network of patents and identified patents with superior network parameters and explained their role in evolution of technology. Chen et al., [4], and Chen et al. [5,6] use citation data to construct citation matrix and subsequently establish a patent citation network. Clustering similar patents in patent citation network at various time periods, they trace the continuation of technologies over time along with changes in members of clusters over time. The notable alternate approach of using keywords to establish technology evolution was proposed by Yoon et al. [21] They proposed an initial text mining of patent documents followed by constructing an incidence matrix. Using incidence matrix, a network was constructed and parameters were calculated for the patents to understand the technology trends. Later Kim et al. [9] proposed a similar approach to construct patent maps and eventually develop a semantic network of keywords to understand technology evolution of emerging technologies. Unlike aforesaid approaches, Adomavicius et al. [1] proposed an ecosystem model of technology evolution which considers a group of interrelated and interdependent technologies to capture the technology evolution, rather than focusing on a technology in isolation. The approach conceptualizes an ecosystem of interrelated technologies, where each technology in the ecosystem can take three different roles, viz. component, product and support/infrastructure. For any given two technologies then there are nine paths of interactions possible establishing co-evolution of all technologies in the ecosystem.

III. METHODOLOGY

Our paper attempted to combine the ecosystem model of technology evolution with network analysis approach. We considered the cochlear implant device technology along with its interrelated and interdependent technologies in terms of US patent classifications numbers, thus representing an ecosystem of technologies. Constructing a network of patent classes with nodes representing unique patent classification numbers and edges representing their co-occurrence, network parameters were computed for each node. Patent classification network across various time periods were compared to understand the changes in intensity of interdependence among the patent classes, emergence and disappearance of patent classes across networks, thus capturing technology evolution. The methodology of the study is given in Fig.1 and explained subsequently. Steps 2 to 4 were repeated separately for every time period considered.

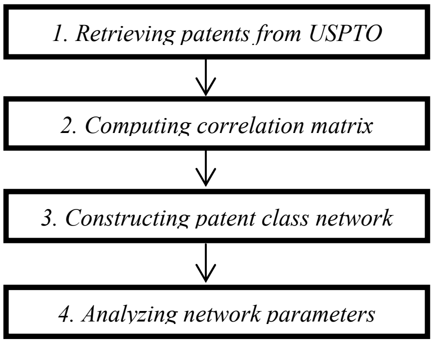

Fig. 1 Overall methodology

A. Retrieving patents from USPTO

Patents related to cochlear implant technologies were searched in US Patents and Trademarks Office (USPTO). US Patent classification "607/57", identified as a technology class relevant to cochlear implant technologies was used to retrieve relevant patents from USPTO. Though prior technology on external hearing aids were available in specific patent classes since 1900 (Class 181, estd. 1900, Class 381, estd. 1983) in form of physics or acoustics related to hearing and external hearing aids, inventions related to implantable hearing aids started from 1977 (Class 607, etsd. 1993). Patents granted during 1977-2012 (n=345) were included in the sample after refining the sample using keywords. Patents with universities as assignees were identified (n=32). Patents are sorted based on year of filing and then segregated into three time periods for further analysis. The first 17 years had 55 patents. The second time period was defined when the growth increased, had 148 patents in this period of 8 years. The third time period, also a growing one, consisted of 142 patents in a period of 6 years. Time period 1 can be called the technology initiation stage and 7 of 55 patents filed between years 1977 to 1994, were from universities. Time period 2 can be called the growth stage of the technology life cycle, filed between years 1995 to 2003, and about 10 of the 148 patents, were from universities. Time period 3 also called the growth stage included 142 patents filed between years 2004 to 2010, of which 15 were from universities. Details on patent classes mentioned in each patent along with the main one i.e., Class 607/57, were captured for use in further network analysis.

B. Computing correlation matrix

Similar to the formulation of incidence matrix proposed by Yoon et al. [21], a correlation matrix of patent classes showing the association of classes was computed. This correlation matrix is a prerequisite for network construction. Lesser correlation values were removed from the matrix to eliminate weak edges in the resulting patent class network. By trial and error method [21] a threshold correlation value of 0.3 was chosen, so that correlation values below 0.3 were made 0.

C. Constructing patent class network

Correlation matrix obtained from the previous step was fed as input to a network analyzing software for construction of patent classes network and computation of network parameters of each patent class. An undirected network graph was chosen, since there is no flow of knowledge or information from one node to another unlike patent citations, where a flow of knowledge occurs between citing and cited patent pair.

D. Analyzing network parameters

Upon the construction of patent class network, the network parameters like degree centrality, closeness centrality and betweenness centrality measures were computed for each node. These parameters are defined in the next section.

IV. ANALYSIS

Degree centrality score of a node (namely a patent class) is a measure of number of nodes connected to that particular node under consideration [19] It is proportional to the probability of obtaining resources from other nodes. A node with higher degree centrality has more probability to diffuse knowledge to or gain from other nodes. Degree centrality is computed using the following equation;

$$d(i) = \sum_j m_{ji} \quad \text{… (i)}$$

where, $m_{ji}=1$ if patent class i and patent class j are present together in a particular patent.

Betweenness centrality score of a node is a measure of how often that specific node is located on the shortest path between other nodes in the network [19] Betweenness centrality is computed using the following equation;

$$b(i) = \sum_{j,k\neq i} \frac{g_{jik}}{g_{jk}} \quad \text{… (ii)}$$

where, g_{jk} is the shortest path between patent class j and patent class k.

g_{jik} is the shortest path between patent class j and k that contains patent class i

Generally, a node located on the shortest path between two nodes act as an intermediary connecting two nodes which are not connected directly. A node with higher betweenness centrality score can be considered as those located at the core of the network.

Closeness centrality score of a node is defined by the inverse of the average length of the shortest paths to/from all the other nodes in the network [19] A higher closeness centrality score denotes higher influence of a node on other nodes. Closeness centrality is computed using the following equation;

$$c(i) = \sum_{j=1}^{N} \frac{1}{d_{ji}} \quad \text{… (iii)}$$

where, $d_{ji}=1$ is the shortest path from patent class j to patent class i.

V. RESULTS

A. Patent classes network for time period 1

Consolidating the patent class/classes mentioned in the patent documents fetched a total of 46 unique patent classes interconnected or interrelated with Class 607/57, during time period 1. An undirected network of these patent classes is shown in Fig.2. White circles denote presence of research activities by universities along with industries, hospitals and individuals, while dark circles denote absence of university research activities in those patent classes.

Network parameters like degree, betweenness and closeness centrality for each patent class were computed. List of 10 patent classes with higher scores in each network parameters are shown in Table 1. Patent classes shown in bold denote presence of university R&D activities in those specific patent classes. From Table 1 (column 1), certain subclasses of Class 607 related to various modules of electrical therapeutic systems like signal generation, communication circuits, energy sources, sensing and output controlling, organ stimulating functions are found to have higher probabilities to diffuse or absorb knowledge with other connected patent classes. Apart from modules of Class 607 related to electrical therapeutic systems mentioned above from column 2 of Table 1, modules of Class 600 and 381 primarily related to surgically implanted hearing aids, signal processing like spectral control and housing for hearing aids can be considered as core of the network from their betweenness centrality scores. From column 3 of Table1, modules of Class 607 related to electrical therapeutic systems mentioned above (observed in degree and betweenness centrality measures), modules of Class 600 related to body therapy using magnetic field application, modules of Class 381 related to testing of hearing aids and modules of Class 206 related to packaging of therapeutic materials are found to have higher influence on other patent classes during time period 1, based on their closeness centrality scores. Universities' R&D presence is observed in various modules of Class 607 mentioned earlier and modules of Class 381 related to spectral control of hearing aids signals.

TABLE.1 PATENT CLASSES WITH SUPERIOR CENTRALITY SCORES DURING TIME PERIOD 1

Rank	Degree centrality	Betweenness centrality	Closeness centrality
1	**607/66**	**607/66**	600/13
2	**607/60**	607/68	600/12
3	607/72	381/312	381/60
4	**607/74**	**607/60**	206/438
5	**607/61**	**607/61**	**607/66**
6	607/62	607/32	**607/60**
7	607/48	600/25	**607/61**
8	607/44	**381/320**	607/68
9	607/42	381/328	607/72
10	607/40	381/325	**607/74**

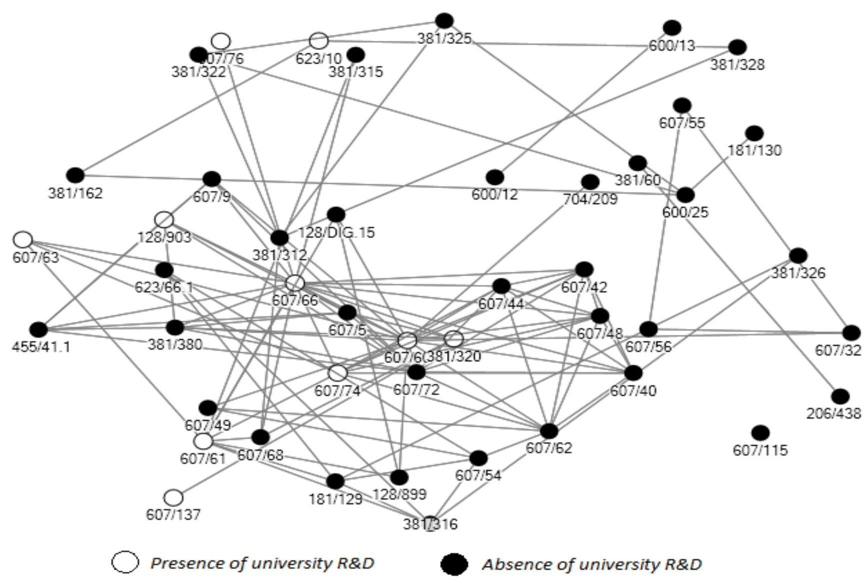

Fig. 2 Patent classes network for time period 1

B. Patent classes network for time period 2

Consolidating the patent class/classes of time period 2, 57 unique patent classes interconnected or interrelated with Class 607/57 were identified. An undirected network of these patent classes is shown in Fig.3. Patent classes with superior centrality scores are shown in Table 2. From degree centrality (column 1), we can observe that subclasses of Class 381 related to modules of stereophonic hearing aids and their remote controlling, testing and housing have largely replaced modules related to Class 607 of time period 1. Specific subclasses of Class 607 related to energy sources, Class 600 related diagnostic testing, Class 623 related to implantable prosthesis and Class 455 related to telecommunications exhibits higher probability for knowledge diffusion or absorption. Specific subclasses of Class 381 related to modules of stereophonic hearing aids and housing, Class 607 related to energy sources, sensors, stimulator housing and Class 600 related diagnostic testing are found to act as the core of the network based on betweenness centrality scores for time period 2 (column 2). Closeness centrality measures (column 3) indicate that specific subclasses of Class 424 related to drugs and body treating compositions for implants, Class 381 related to audio processing systems, Class 324 related to measuring, testing devices, fault detection and location, Class 600 related to structures of electrode inserted into ear, Class 606 related to electrode guide means and Class 307 related to substitute storage batteries are more influential in time period 2, which is different from time period 1. Interestingly, universities have focused on modules of Class 381 which has superiority in terms of degree and betweenness centrality and modules of Class 424 which has superiority in terms of closeness centrality.

TABLE.2 PATENT CLASSES WITH SUPERIOR CENTRALITY SCORES DURING TIME PERIOD 2

Rank	Degree centrality	Betweenness centrality	Closeness centrality
1	**381/326**	**381/312**	**424/422**
2	**381/312**	**381/326**	**424/198.1**
3	607/61	381/23.1	381/330
4	381/23.1	607/61	381/328
5	600/559	607/33	324/537
6	607/33	607/36	324/528
7	381/60	600/559	600/379
8	623/11.11	607/62	606/129
9	381/315	607/2	600/585
10	455/414.1	607/116	307/66

C. Patent classes network for time period 3

Consolidating the patent class/classes, 68 unique patent classes interconnected or interrelated with Class 607/57 in time period 3. An undirected network of these patent classes is shown in Fig.4. Patent classes with superior centrality scores are shown in Table 3. Observing patent classes with superior degree centrality scores (column 1), we can discover that subclasses of Class 607 related to electrical therapeutic systems promoting auditory functions by implanting energy inside inner ear are found to exhibit higher probability for knowledge dissipation or absorption. Apart from modules of Class 607 aforementioned, module related to generation of complex signals, specific modules of Class 600 related to structures of electrodes placed inside ear and their diagnostic testing are found to act as core of network with superior betweenness centrality scores (column 2). Closeness centrality measures (column 3) indicate that subclasses of Class 977 related to nanotechnology for body treatment or diagnosis, nanowires or quantum wires are found to be highly influential during time period 3. Also specific subclasses of

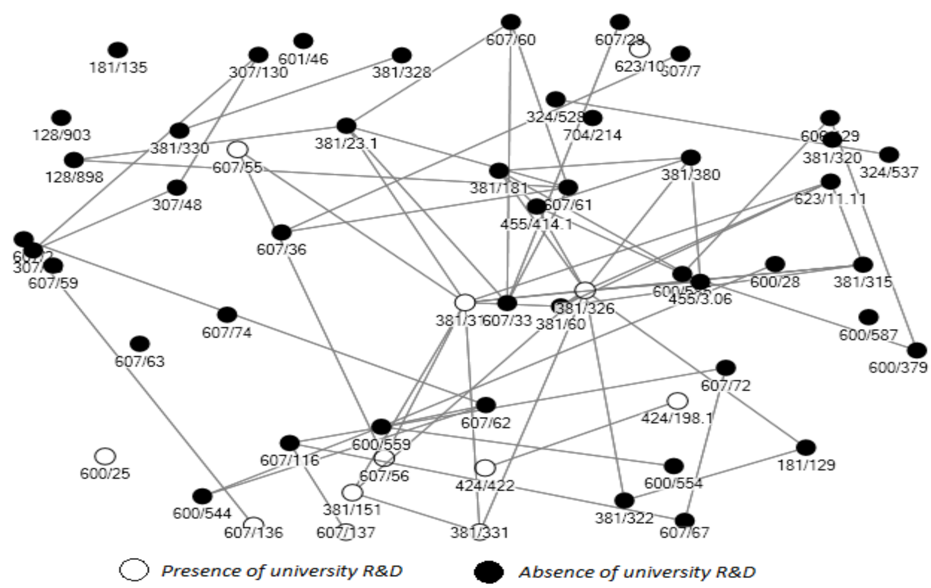

Fig. 3 Patent classes network for time period 2

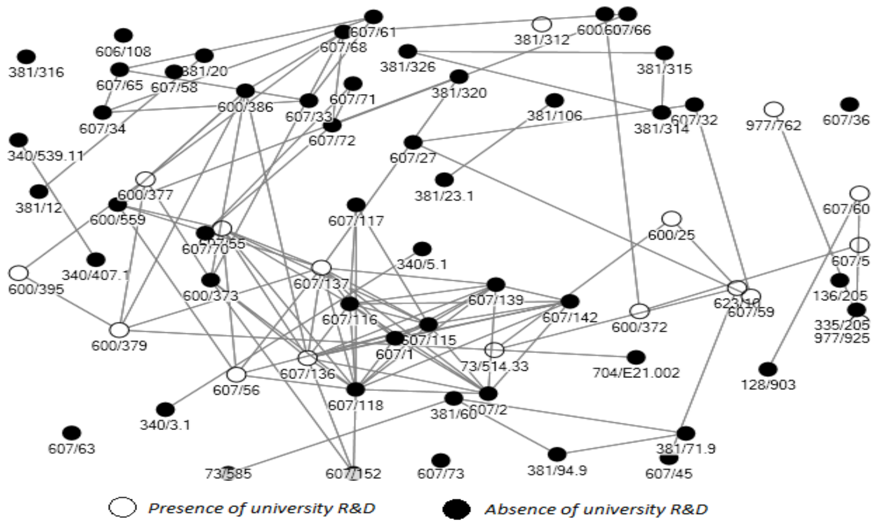

Fig. 4 Patent classes network for time period 3

Class 381 related to audio signal processing, FM final modulations, hearing aids, Class 340 related to communications for portable devices, intelligence comparison controlling systems are also found to be highly influential in time period 3. It was interesting to observe a set of patent classes with superior closeness during time period 3, different from time period 2 in Table 3. Universities have focused on modules of Class 600, 607 related to promotion of auditory function using stimulators and placing electrode in inner ear, which has superiority in terms of degree and betweenness centrality. It was interesting to observe that universities are focusing on modules of Class 977 dealing with nanotechnology and have strived to retain their research focus on highly influential patent classes of across time periods 2 and 3.

TABLE.3 PATENT CLASSES WITH SUPERIOR CENTRALITY SCORES DURING TIME PERIOD 3

Rank	Degree centrality	Betweenness centrality	Closeness centrality
1	607/118	607/68	**977/925**
2	**607/137**	**607/137**	**977/762**
3	**607/136**	600/373	381/20
4	607/115	**607/136**	381/12
5	607/116	600/386	381/23.1
6	607/2	607/72	381/106
7	607/139	607/118	340/539.11
8	607/1	**600/379**	340/407.1
9	**607/55**	**600/377**	340/5.1
10	607/142	600/559	340/3.1

D. Emerging and disappearing patent classes across time periods

Analyzing the list of disappearing patent classes in time period 2 and 3 in Table a (2) of the Annexure, we observe that aspects of devices like concepts of acoustics and telecommunications, transducers functioning, casing and fasteners of device, stimulators and speech signal formatting are found to disappear across time periods. Interestingly, the list of emerging patent classes in time period 2 and 3 in Table a (3) of Annexure shows that technologies generally related to diagnostic testing of device, energy storage devices, sound quality enhancement techniques like binaural, stereophonic, quadraphonic, noise cancellations and amplitude control, energy applicators and complex signal generators, mechanical waves measuring and nanotechnology are found to emerge during time period 2 and 3. Detailed description of certain subclasses of Class 307, Class 324, Class 424 and Class 601 emerging in less frequency only in time period 2 and disappearing in time period 3 are not included in the Annexure. Fig. 5, 6 and 7 shows the frequency of various patent classes during time periods 1, 2 and 3 respectively, capturing the increase, decrease, disappearance and emergence of research in various patent classes. We can propose that over the time periods research paradigm has shifted from functional aspects of the device to feature enhancements of the devices. Further analysis on these patent classes and related patents can give us better insights about the technology evolution.

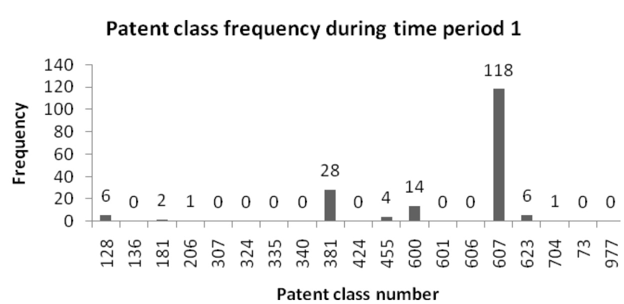

Fig. 5 Patent class frequency during time period 1

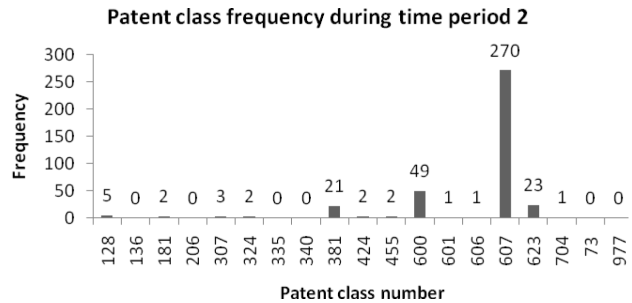

Fig. 6 Patent class frequency during time period 2

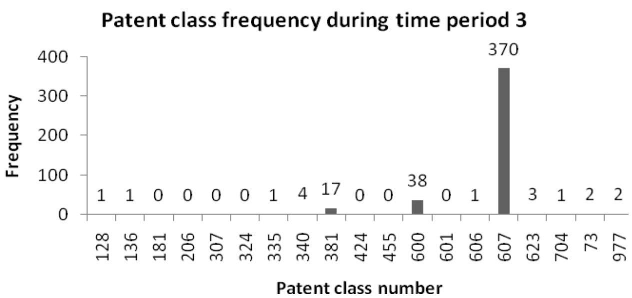

Fig. 7 Patent class frequency during time period 3

VI. CONCLUSIONS

This study proposed a framework for capturing technology evolution using patent classifications supported by the techniques of network analysis. Considering a group of interrelated and interdependent patent classes in cochlear implant device technology, patent class networks were constructed across three different time periods. Network parameters like degree centrality, betweenness centrality and closeness centrality were computed to understand the relative position or importance of each patent class in the network. At every time period a new set of patent classes turns out to be superior than others, enabling us to capture the dynamics of non-uniform mutual influence existing between the patent classes and thus capturing the evolution of the technology. Understanding of these influences can be a trigger for future innovative trends in the technology considered. Closeness centrality measures across time periods were of profound importance, since they capture the influence of various other classes on the cochlear implant technology over time. While at time period 1 four classes influenced the technology, time period 2 witnessed a new set of six patent classes influencing the technology. During time period 3, a new set of patent classes seemed to have profound influence on shaping the innovations in the technology, including nanotechnology. A special focus on university's position in the patent class network gives us better insights. It was interesting to note that universities strived to sustain their research focus on patent classes with superior closeness centralities during time period 2 and 3. These are drugs and body treating compositions for implants and nanotechnology. Taking insights from changing network centrality scores of patent classes and their emergence or disappearance over time can help make better technology forecasts and thus support in taking better strategic decisions in high-tech management.

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ANNEXURE

TABLE A (1). LIST OF PATENT CLASSES DURING TIME PERIOD 1 (1977-1994)

Time period 1 (1977-1994)	Class 128: SURGERY 899: Devices placed entirely within body and means used therewith 903: Radio telemetry DIG.15 Hook and loop type fastener Class 181: ACOUSTICS 126 Anatomic or Prosthetic relations 128 Ear and mouth 129 Ear 130 Auditory canal insert Class 206 SPECAIL RECEPTACLE OR PACKAGE 438 For body treatment article or material (i.e., surgical or therapeutic type) Class 381 ELECTRICAL AUDIO SIGNAL PROCESSING SYSTEMS AND DEVICES 58 Monitoring/Measuring of audio devices 60 Testing of hearing aids 150 Electro-acoustic audio transducer 162 Detail of mechanical vibration coupling to transducer 182 Plural or compound reproducers 370 Headphone 374 Particular support structure 380 Ear insert or bone conduction 312 Hearing aids, electrical 315 Remote control, wireless, or alarm 316 Frequency transportation 320 Spectral control 322 Specified casing or housing 325 Cerumen protection 326 Non-air-conducted sound delivery 328 Ear insert Class 455 TELECOMMUNICATIONS 39 Transmitter and receiver at separate stations 41.1 Near field Class 600 SURGERY 9 Magnetic field applied to body for therapy 12 Magnetic element placed within body 13 Electromagnetic coil 25 Surgically implanted vibratory hearing aid Class 607: SURGERY: LIGHT, THERMAL, AND ELECTRICAL APPLICATION 1 Light, thermal and electrical application 2 Electrical therapeutic systems 5 Cardioverting/defibrillating 9 Heart rate regulating 32 Communicating with pacer 54 Producing visual effects by stimulation 55 Promoting auditory function 56 Producing aural effects by stimulation 60 Telemetry or communications circuits: 61 Energy source outside generator body 62 Output controlled by sensor responsive to body or interface condition 63 Promoting patient safety or comfort 66 Generating more than one signal 68 Generating complex signals 72 Pulse signal 74 Bipolar pulses 76 Oscillating signals 40 Stimulating bladder or gastro-intestinal tract 42 Stimulating respiration function 44 Treating hypertension 48 Directly or indirectly stimulating motor muscles 49 For walking assistance 115 Electrical energy applicator 116 Placed in body 137 Inner ear (e.g. Cochlea) Class 623: PROSTHESIS PARTS THEREOF, OR AIDS AND ACCESSORIES THEREFOR 10 Ear or nose prosthesis 66.1 Miscellaneous CLASS 704: DATA PROCESSING SPEECH SIGNAL PROCESSING, LINGUISTICS, LANGUAGE TRANSLATION, AND AUDIO COMPRESSION/DECOMPRESSION 200 Speech signal processing 201 For storage or transmission 205 Frequency 206 Specialized information 209 Formant

TABLE A (2). LIST OF PATENT CLASSES DISAPPEARING DURING TIME PERIODS 2 AND 3

Time period 2 (1995-2003)	Class 128: SURGERY 899: Devices placed entirely within body and means used therewith DIG.15 Hook and loop type fastener Class 181: ACOUSTICS 126 Anatomic or Prosthetic relations 128 Ear and mouth 130 Auditory canal insert Class 381 ELECTRICAL AUDIO SIGNAL PROCESSING SYSTEMS AND DEVICES 150 Electro-acoustic audio transducer 162 Detail of mechanical vibration coupling to transducer 312 Hearing aids, electrical 322 Specified casing or housing 325 Cerumen protection Class 600 SURGERY 9 Magnetic field applied to body for therapy 12 Magnetic element placed within body 13 Electromagnetic coil Class 607: SURGERY: LIGHT, THERMAL, AND ELECTRICAL APPLICATION 1 Light, thermal and electrical application 2 Electrical therapeutic systems 9 Heart rate regulating 54 Producing visual effects by stimulation 76 Oscillating signals 40 Stimulating bladder or gastro-intestinal tract 42 Stimulating respiration function 44 Treating hypertension 48 Directly or indirectly stimulating motor muscles 49 For walking assistance Class 623: PROSTHESIS PARTS THEREOF, OR AIDS AND ACCESSORIES THEREFOR 66.1 Miscellaneous CLASS 704: DATA PROCESSING SPEECH SIGNAL PROCESSING, LINGUISTICS, LANGUAGE TRANSLATION, AND AUDIO COMPRESSION/DECOMPRESSION 200 Speech signal processing 201 For storage or transmission 205 Frequency 206 Specialized information 209 Formant
Time period 3 (2004-2010)	Class 181: ACOUSTICS 126 Anatomic or Prosthetic relations 128 Ear and mouth 129 Ear Class 381 ELECTRICAL AUDIO SIGNAL PROCESSING SYSTEMS AND DEVICES 150 Electro-acoustic audio transducer 182 Plural or compound reproducers 370 Headphone 374 Particular support structure 380 Ear insert or bone conduction 312 Hearing aids, electrical 322 Specified casing or housing 328 Ear insert Class 455 TELECOMMUNICATIONS 403 Radio telephone systems 414.1 Special device Class 607: SURGERY: LIGHT, THERMAL, AND ELECTRICAL APPLICATION 1 Light, thermal and electrical application 2 Electrical therapeutic systems 62 Output controlled by sensor responsive to body or interface condition 72 Pulse signal 74 Bipolar pulses

TABLE A (3). LIST OF PATENT CLASSES EMERGING DURING TIME PERIODS 2 AND 3.

Time period 2 (1995-2003)	Class 381 ELECTRICAL AUDIO SIGNAL PROCESSING SYSTEMS AND DEVICES 1 Binaural and stereophonic 23.1 Hearing aid Class 600 SURGERY 300 DIAGNOSTIC TESTING 372 Structure of body-contacting electrode or electrode inserted in body 373 Electrode placed in body 379 Electrode in ear 559 Ear or testing by auditory stimulus Class 607: SURGERY: LIGHT, THERMAL, AND ELECTRICAL APPLICATION 1 Light, thermal and electrical application 2 Electrical therapeutic systems 9 Heart rate regulating 33 Energy source external to generator or body 36 Feature of stimulator housing or encapsulation 59 Control signal storage 115 Electrical energy applicator 116 Placed in body 136 External auditory canal
Time period 3 (2004-2010)	Class 136: BATTERIES: THERMOELECTRIC AND PHOTOELECTRIC 200 Thermoelectric 205 Electric power generator Class 335: ELECTRICITY: MAGNETICALLY OPERATED SWITCHES, MAGNETS AND ELECTROMAGNETS 205 Permanent magnet-actuated switches Class 340: COMMUNICTIONS: ELECTRICAL 1.1 Selective 3.1 Monitoring in addition to control 5.1 Intelligence comparison for controlling 384.1 Audible indication 404.1 Pneumatic-type sound producer 500 Condition responsive indicating system 531 With particular coupling link 539.1 Radio 539.11 Including personal portable device Class 381 ELECTRICAL AUDIO SIGNAL PROCESSING SYSTEMS AND DEVICES 1 Binaural and stereophonic 2 Broadcast or multiplex stereo 3 FM final modulation 4 AM subcarrier 12 Stereo indicators 19 Quadrasonic 20 Matrix 71.1 Acoustical noise or sound cancellation 71.8 Counterwave generation control path 71.9 Non-acoustically derived reference signal 94.1 Noise or distortion suppression 94.9 Feedforward circuitry for transducer compensation 104 Including amplitude or volume control 106 with amplitude compression/expansion 312 Hearing aids 314 programming interface circuitry Class 600: SURGERY 300 Diagnostic testing 372 Structure of body-contacting electrode or electrode inserted in body 373 Electrode placed inside the body 377 Electrode implanted in body 386 Means for attaching electrode to body 393 Plural electrodes carried on single support 395 Electrode composition Class 606: SURGERY 1 Instruments 108 Means for inserting or removing conduit within body Class 607: SURGERY: LIGHT, THERMAL, AND ELECTRICAL APPLICATION 1 Light, thermal and electrical application 2 Electrical therapeutic systems 9 Heart rate regulating 27 testing or monitoring pacer function 34 Alterable energy source configuration 45 Treating mental or emotional disorders

	58 Stimulating for aversion and substance abuse therapy 65 Signal generated by induction coil circuit 68 Generating complex signals 70 With two pulse signal components 71 With one pulse and one oscillating signal component 72 Pulse signal 73 Random or pseudo-random pulse pattern 115 Electrical energy applicator 116 Placed in body 117 Spinal cord 118 Applicator placed around the stimulated nerve 139 Head supported 142 Applying electrical energy to the heart through intact skin 152 Flexible sheet or resilient pad Class 704: DATA PROCESSING: SPEECH SIGNAL PROCESSING, LINGUISTICS, LANGUAGE TRANSLATION, AND AUDIO COMPRESSION/DECOMPRESSION E21.001 MODIFICATION OF AT LEAST ONE CHARACTERISTIC OF SPEECH WAVES E21.002 Speech enhancement, e.g., noise reduction, echo cancellation, etc. Class 73: MEASURING AND TESTING 488 SPEED, VELOCITY, OR ACCELERATION 514.01 Acceleration determination utilizing inertial element 514.16 Specific type of electric sensor or specific type of magnetic sensor 514.33 Resistive sensor 570 Vibration 584 By mechanical waves 585 Including ear or hearing testing Class 977: NANOTECHNOLOGY 700 Nanostructure 762 Nanowire or quantum wire 902 Specified use of nanostructure 904 For medical, immunological, body treatment, or diagnosis 925 Bioelectrical