Convergence of Technologies

Anuroop Banerjee

Abstract — Science has to go through a lot of ordeals and perseverance. The scientific inventions lead to economic viability and dominance in myriad arenas. The growth of technology has been nonlinear. It acquires newer zeniths with admirable surges from time to time that led technology flow through various meandering avenues and the imminent prognosis unveils the renaissance in technology is knocking at our doorsteps. The tech-utopians consider that the convergence of Nanotechnology, biotechnology, Information Technology, electronics, aerospace and cognitive sciences would possibly intermingle resulting in the most anticipated realignment of interdisciplinary boundaries. Convergence of technology will aggravate the fiefdoms of sciences and may re-define the realm of technology; the 'insurmountable' will perhaps turn into 'accolades' in the forthcoming years, who knows? Communication Technology has already merged with the embellished Information technology leading to Information Communication and Technology. With the advent of Nanotechnology, the privileges for the confluence of Bio-Nanotech-IT seem pre-emptive, which might give birth to Nano Robots. In the future, the fields of micro electronics, material sciences and electronics may give way to integrated Silicon electronics and photonics. The infusion of ICT with Biotechnology can lead to the development of Intelligent Biosciences which might cause 'elixirs' in the lives of human beings. Probabilities of revolutions in the aerospace industry would suffice with the convergence of the ICT, Nanotechnology and aerospace. Convergence of technologies may have several hind sides like all other developments in the technical arena. Such renaissances in the fields of technology will help moping out the gnawing plague that causes jitters and crisis of human life, ameliorate the incidences of chances of inter planetary transportation with the devising of highly reliable and intelligent aerospace systems, induce cost effectiveness in the technical parlances and thus cause multitude of improvements humans can contemplate only in their dreams. Convergence of technology is a magical wand which can enforce societal transformation for the better.

Keywords— Age of Transition, Computer Communication Revolution, Cost-effective Technologies, Challenges at the Disposal of R&D, Convergence in Communication and broadcasting, Nanotechnology-Biology-Information Technology revolution, Renaissances in Technology

I INTRODUCTION

All and sundry are aware of the truth that term "Modernization" explains a 'relative' bettered development of an existing form of an entity or a field. Human beings are the most premier of life forms existing in this universe! Every time a precipice or predicament came by the way of humans, they took recourse to the vindictive measures fathomed by science and technology to refrain from the gnawing indifferences owing to catch22s and glitches. In a nutshell the technical parlances have sought for steep rise to a pinnacle of success, improving their fiefdoms by the ingenuous pursuits of science and technology, down the decades. Treaties are summing up between nations striving towards holistic developments in the domains of medicines, molecular biology and biotechnology and other cognitive advancements in this Age of Transition, we live in!

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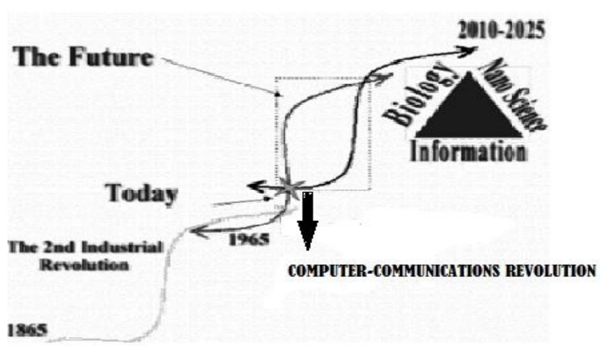

Fig. 1: An S-Curve portraying chronological technological development
The Age of Transition lies between 2010 and 2025 approx

The advent of newer regimes in myriad disciplines owing to two patterns of scientific-technological changes: an overlap of a computer-communications revolution and a nanotechnology-biology-information technology revolution are gaining ground. IT has a lot to offer towards emergence of top-notch

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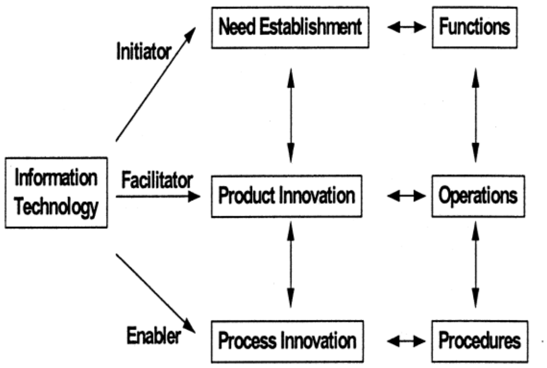

Fig. 2: The domains of Information Technology (IT) are over a wide gamut and interweaved.

II INDUSTRIAL REVOLUTION POWERED BY COMPUTERS

The advent of computers ever since their inception has had savouring impacts on the scientific developments. The first computer to have been built, Tradic in

1955 had only 800 transistors. The Pentium II chips developed in the early 21st century has 7,500,000 transistors. Within a gamut of 15 to 20 years, there will be minute chips accommodating over one trillion transistors. The electronic industry, presently operating primarily in the micron scale is entitled to advance forward into inception of Nano scales, in the near future. However those scales of change when graphed portray enormous implications. With accordance to the present scenario, we are merely one-fifth of the way into procuring a huge computer revolution.

Communications capabilities will see a big leap forward and will impose a better impact than that of computing power, in today's context. Most of the homes today get ready access to Internet @ 28K to 56K bits per seconds. Considering the inept giant strides to success forward, within a few years, a host of newfound combination of technologies will be dominant for compressing information with larger capacities (especially fibre optics and cables) and entirely newer approaches (such as incorporation of satellite direct broadcast for the Internet) may ameliorate or push forth the household accesses up to at least six million bits per second or believed to be up to the benchmark of 110 million bits required for uncompressed motion pictures. An amazing range of opportunities will thus open up, with the oodles of development in high definition televisions and virtual systems. The use of cell phones for day to day activities has seen a rapid development. As a result of which, cells are being used as an universal utility device such as voice, credit cards, internet and television applications using a sole portable hand-held phone.

The communications-computer revolution and the earlier Industrial Revolutions are in fact both examples of the phenomenal concept of an "S"-curve. The S-curve depicts the evolution of technology down the ages. Science and technology begins to accelerate slowly in its salad days, and then as knowledge and experience accumulates, they grow much more rapidly.

Finally, once the field has matured the rate of change levels off. The resulting pattern looks more like an 'S'. An overall S-curve is made up of thousands of smaller integral iota of small parts of the S-curves of technological growth. Thus the stepping stones to successes in any field will be borne by the branch of Information Technology which is in high demand, worldwide.

III CHARACTERISTICS OF THE AGE OF TRANSITION

The inkling about the incumbent changes was revealed by Boulding, thirty six years ago. Since then the markets have risen to the zenith through various ups and downs. The present scenario worldwide revolves around the synergies of technical congresses of various domains to elucidate the paths towards developing a future on the premises of the convergent technologies. This will create not only a host of new job opportunities but also pave the paths for rampant development in the future. Let's have a brief knowledge of the characteristic pros and cons of this period:

- *Costs Will Decrease*: there will be substantial reduction in costs primarily because keeping the machines/robots will ask for lesser expenditure, down the years for a company compared to keeping human staffs!
- *Systems Will Be Customer Centred:* Systems will provide sublime services.
- *Convenience Will Be Highly Regarded 24X* 7: There will be a higher incidence of e-customers as a result.
- *Middle Men Will Disappear*: The middle men will cease to exist from the realm of businesses gradually as e-commerce gets most popular worldwide.
- *Changes from Anywhere Imminent:* The potentials of a man should never be underestimated. The idea, if relevant should be catered to, rather than eyeing the pedigree of the individual who has proposed steps for certain makeovers.
- *Venture Capitalists and Entrepreneurs Will Focus on Opportunities and Successes:* "Starting small but dreaming big" should be the buzzword capitalists should reckon with.
- *Real Breakthroughs and Technological Paradigms Will Create New Products and Newer Expectations Quickly*
- *Partnering will be Essential:* The domains of the fields, post-convergence will be so vast that partnership in business will be a key to prosperity.

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IV TRENDS IN THE CONVERGENCE OF COGNITIVE SCIENCES AND ICT

Foremost Convergence Successful Years Ago:
Just like Information Technology, Communications too has a wide fiefdom. Both of these two fields had to go hand-in-hand. The researchers thought the smart way round to merge these two disciplines and coined it Information & Communication Technology or dubbed ICT.
Cognitive sciences are the study of the cognitive processes involved in thinking pertaining to the brain. The brain is seen as the material substrate for thought. The 'hardware' of the brain – the neurons – lead to the development of the cognitive processes such as feelings, observing, memorising, diverting attention, coming into action, exerting control, learning, affective capacities just akin to the 'software'. The brain grows as we age, and this 'intertwined growth' of the brain is termed as the plasticity of the brain. The new insights in brain research (based on a direct study of brain activity – the cognitive neurosciences) are analogous to 'Connectionism' in the computer sciences. This enables 'learning' computer systems to be made. Connectionism assumes a network of processors (in the brain: the neurons) which can generate output signals (in the brain: the firing of the neurons) based on the input of other processors. The brain has intricate networks and taking special care of its delicate organisation was catered to over the past decade or so. Incidentally there was an obvious convergence of the Cognitive Sciences with ICT. The domains in which the convergence began to be implemented were:

A. *Cognitive Systems Model*: Robots form a class of cognitive systems used for high profile researches. They are impeccable in their work and has highly efficient. The Japanese robotic research showed real mettle and prolific imagination of the Japanese researchers. The Japanese society is aging fast (twice the rate of Europe) and Japan expects to be able to use robots to care for older people; simple robots for cleaning activities – such as hovering – already exist. The more complex forms of care also require robots capable of offering affection and able to communicate with their surroundings. Japan has been heavily investing in a research programme with the title "Humanoid and Human Friendly Robotics Systems" This has led to a humanoid robot (a robot with a human appearance) that is 160 cm tall, weighs 90 kg which can move at a speed of two kilometres per hour (also over uneven surfaces).
B. *Image Processing:* Image processing techniques are one of the most fascinating aspects of the convergence between cognitive sciences and ICT. Advanced "functional Magnetic Resonance Imaging" (fMRI) provides a highly advanced and detailed sketch of the brain. This fMRI makes use of the magnetic characteristics of water protons in brain tissue.
C. *Pattern Recognition*: The aspects of recognition and classification of structures led to the inception of various pattern-recognition technologies. This applies to the recognition and information processing of language and speech. A multitude of mathematical modelling techniques form the basis of pattern recognition. Trends within pattern recognition mainly concern refining the available mathematical instruments & algorithms and the application of these instruments in everyday life such as speech and face recognition and image recognition techniques such as those used for fMRI (functional Magnetic Resonance Imaging.
D. *Human-Machine Interaction*: Implants are effective tools elucidating the prevalent scenario of human-machine interaction. Neurosurgery is capable of inserting brain implants with considerable precision. The *Deep Brain Stimulator* (DBS) is a neuro stimulator used to control Parkinson's disease. DBS is the pacemaker for the brain. A wire no thicker than a human hair is inserted into an area of the brain that controls the movement of the human body. The wire is led back under the skull to a small device inserted under the collar bone. The device sends small electrical impulses via the wire to the selected area of the brain and overcomes the uncontrolled movements which are characteristic of Parkinson's disease—degenerative brain diseases, such as chronic pain, problems with the spinal cord, epilepsy, depressions and spastic muscles. Another instance of Human Machine interaction in vogue is "Cochlear implants which enable deaf people to hear".

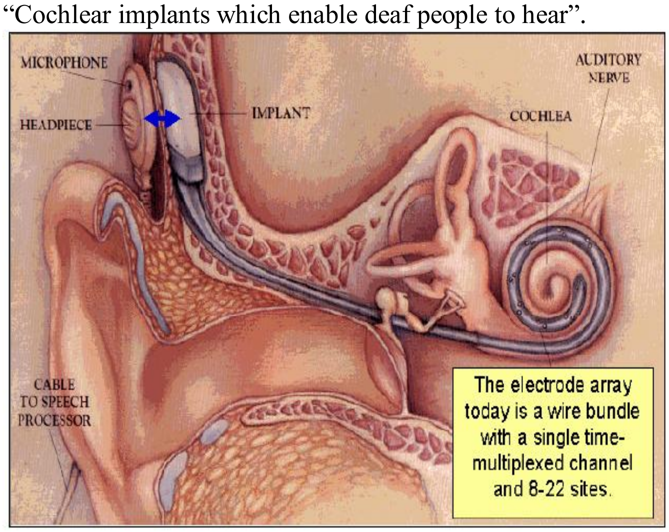

Fig. 3: Diagram for Cochlear Transplant

A cochlear implant is implemented by means of a small microphone attached to the outside of the ear connected to a speech processor. The processed signals are remotely transmitted to the cochlear implant attached inside the ear. Within the ear the signals are converted by a chip into pulses which are spread over a series of 22 electrodes. The 22 electrodes are in turn connected to the auditory nerve, which transports the pulses to the brain.

- *Drawback*: Sound received in this manner, comes across as a very artificial sound. Patients must learn to distinguish speech from noise. People, who have been deaf since birth, cannot learn to talk with this method.

- *Scope for Betterment*: Research is being carried out into developing ways of improving how the electrodes connected to the auditory nerve. Better transmission techniques are also being sought for. Using the MP3 format to augment the clarity in hearing and discerning the differences between forms or sound and noise are being aimed at.

V BIO-ELECTRONICS

Bioelectronics comprises a range of topics at the interface of biology and electronics. One aspect of bioelectronics is the application of electronics to problems in biology, medicine, and security. This includes electronics for both detection and characterization of biological materials, such as on the cellular and sub cellular level. Another aspect of bioelectronics is using biological systems in electronic applications (e.g., processing novel electronic components from DNA, nerves, or cells). Bioelectronics also focuses on physically interfacing electronic devices with biological systems (e.g., brain-machine, cell-electrode, or protein-electrode). Applications in this area include assistive technologies for individuals with brain-related disease or injury, such as paralysis, artificial retinas, and new technologies for protein structure-function measurements.

A. *Opportunities for Bioelectronics:* Bioelectronics has had constant advances in semiconductor technology coupled with advances in surface chemistry and their application to life sciences research. Much of the work that has been done in the bioelectronics field since the 1990s has been focused on creating better biosensors by integrating bio molecules with semiconductors. For decades, semiconductor technology has advanced at an exponential rate and is described by Moore's law, which states that the number of features in a given area of substrate doubles every 18–24 months. A result of Moore's law is that the computing power and capabilities increase with each generation of device while the cost per function decreases. A plethora of arenas are opening up whereby efficient advancements in the fields of Bioelectronics is feasible, as:

   i. *Biologically-based Sensors and Fabrication:* Cells and their components can be used as biological transducers for measurements or as components in building novel materials or circuits. Biomolecules, in particular antibodies, can also be used as transducers, via their exquisite specificity for complementary molecules. Coupling antibodies with emerging Nano-scale technologies could result in ultra-sensitive detection methods. Bio-inspired fabrication shows promise for constructing Nano scale assemblies, which could lead to significant advances in sensor design and materials technology.

   ii. *Real-Time and Massively Parallel Molecular and Cellular Characterization for Systems Biology:* The nascent field of systems biology using systems engineering approaches to analyze cellular function, is driving the development of new technology that can monitor multiple aspects of cellular behaviour over many time points. Systems biology embodies a new perspective from which to view biological systems and knowledge culled from its approaches could lead to advances in medicine and security.

   iii. *Protection and Restoration of Health:* Advances in miniaturization and power transmission, storage, and generation have allowed implantable medical devices to emerge e.g. artificial retina, Implantable "smart" drug delivery devices, based on micro-electro-mechanical systems (MEMS) and embedded transceivers (i.e., able to sense and respond to their environment and transmit and receive data) instead of passively delivering drugs at pre-defined intervals.

V I TRENDS IN CONVERGENCES & ADVANCEMENTS OF BIOTECHNLOGY AND NANOTECHNOLOGY

There is no unequivocal definition of bio-nanotechnology. This is partly because the convergence is occurring in two directions. On the one hand there are developments within nanotechnology that are applied to biology, biochemistry and the related areas of medicine or pharmaceutical studies. On the other hand biotechnology brings concepts of both self assembly and real physical biological building blocks and fabrication routes to nanotechnology. Both routes lead to a broad range of subsidiary areas, all of which fall under the broad aspect called "Bio-Nano".

Areas of convergence:

a) *Nanotools*: In the realm of life, there is a requisite need for tools to support research into the understanding of biological processes. These tools include microscopy, optical tweezers (technology related to cryo electron microscopy (for augmented 3D views), in which laser bundles are used to pick up individual molecules), imaging techniques and bionanosensors (fabricated via nanotechnology or micro technology, but DNA, proteins, enzymes, whole cells or micro-organisms serve as the detection materials.) and high-throughput micro arrays (biochips or DNA chips constituting of bio receptors(minute dots less than 5 micrometres) which when reacts with certain bio substances under investigation results in fluorescence and thus the dots emanate light). Nano materials, such as spheres of gold with a diameter of several tens of nanometres and carbon nanotubes, play an increasingly important role in biotechnology. In the present context, we see the use of Quantum dots as an alternative to fluorescent labels, which are not stable and quickly dim. The quantum dot is a typical example of ‘real’ nanotechnology. Different types of quantum dots are already commercially available. Recent researches are focused on improving quantum dots for biological applications.

- *The far-reaching fiefdoms of Nanotechnology:* Nanotechnology is not one specific technology, but is an agglomerate of a plenitude of disciplines. Nanotechnology is used in the areas of wireless communication, networks and efficient energy saving. The concept ‘ambient intelligence’ refers to an intelligent environment – house, car, office − that is continually responding to our behaviour and wishes. An example is the intelligent tracking and tracing of products such as drugs or products which can become tainted in the production chain. Ultrasensitive biosensors based on Nano electronics will be developed which can detect extremely low concentrations of cell structures, antibodies or proteins as a result of which better diagnoses and treatments will be possible. Nano biosensors will also support the functioning of intelligent implants, molecular laboratories and non-invasive health tests.

In the area of transport, Nano electronics can support the intelligent use of engines. This will lead to lower fuel use and therefore less air pollution.

In the area of antiterrorism measures and public safety, Nano electronics can be used in observation, alarm and entry control equipment (including biometry: see also biotechnology and ICT). Finally, in the future nanotechnology will make the revolutionary concept of quantum computing possible.

Nano Photonics [2] is another result of convergence of Nanotechnology with ICT in the area of fibre optics for communication, optical data storage and display technology. Developments in nanotechnology will further lead to improvements of these applications. Being able to create the desired photonic bandwidth is the technology with which it will be possible to realise high-speed data communication with fibre optics.

b) *Biological (supported) Fabrication:* This bio Nano area concerns the use of 'living structures' as a factory wherein Viruses or proteins are regarded as a cage or 'reactor vessel' for the manufacturing of nanoparticles. A far-reaching form of convergence is bio mineralisation in which enzymes and viruses are capable of independently producing optical, electronic and magnetic materials as well as ‘bio’fabricating biological materials such as protein Nano fibres. The electronics and sensor industry is also looking for a new method to produce patterned Nano particles, as the present photolithography process will ultimately not be able to cope with the advancing scaling-down of the building blocks in electronics. Eyes are therefore turning to the biological world for a solution.

VII CONVERGENCE OF COMMUNICATIONS AND BROADCASTING

The phenomenon of convergence of the fields of communications and broadcasting led to the perpetrating developments in the broadcasting industry. Technological innovations triggered a merger and thereby division into four categories for convergence according to Fig. 4.

TABLE I

DIFFERENCES BETWEEN BROADCASTING & COMMUNICATION [1]

	Communication	**Broadcasting**
Definition	Sending, transmission and/or receiving codes audio or video signals by wired, wireless or electromagnetic systems.	Transmission of radio communications for being captured and received directly by the public.
Orientation	One to one interaction or personal communications	One to n, one way to many or mass communications
Band	3 KHZ (narrowband)	6 KHZ (broadband)
Major usage purpose	Voice, such as telephones	Video and audio signals

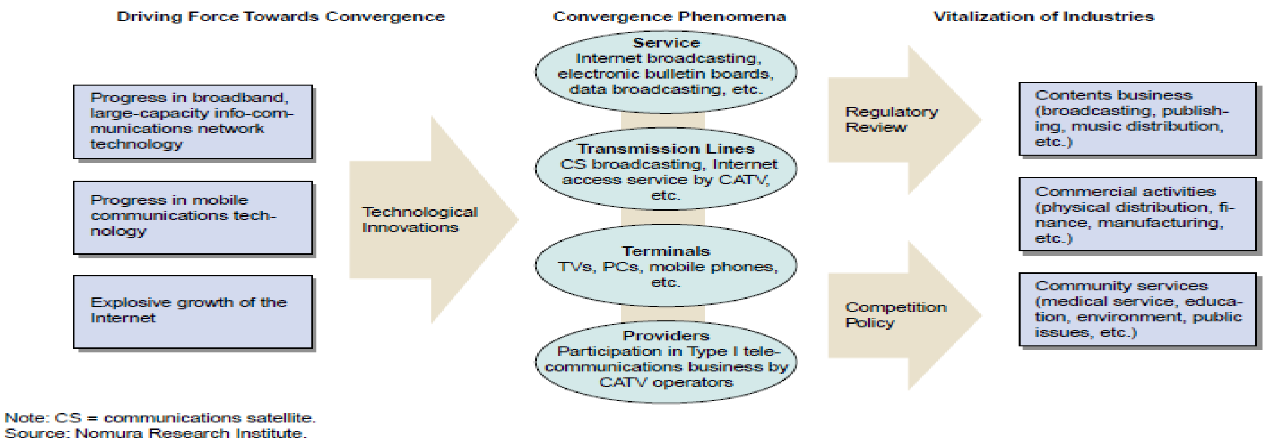

Fig. 4: Phenomenon of Convergence of Broadcasting and Communications

The convergence led to rampant development and thereby boom of the television and satellite broadcasting industry. Internet grew stupendously. Owing to the confluence, there has been incidence in digitization in the realms of this field, adding to a sustained decrease in analogue transmission noises.

VIII CONCLUSION

Challenges at the Disposal of R&D Fellows

i. *Information and Communication Technology*: India is more of a knowledge powerhouse rather than a software powerhouse in the field of ICT. Implementation of virtual platforms in larger numbers is a must for practical implementation & thus development of knowledge in India.

ii. *Energy Causes [4]*: By the end of 2030 when our population will be around 1.4 million demands from the power sector will increase from 130,000MW to about 400,000MW. This inclines to an energy growth rate of 5% per annum. To make India independent of fossil fuel by then, the efficiency of fossil fuels need to rise from 15% at present to 50% within three years time and made commercially available within the next five or six years.

iii. *Automobile Industry*: Future automobile engines need to have better internal combustion diesel engines, systems using alternate fuel sources like hydrogen powered fuel cells and CNT based higher efficiency solar cells need to be incorporated. This will gradually lead to introduction of robotic cars. Indian automobile industry needs to amass US $200 billion by 2016 leading to rise in export component from US $45billion to US 50 billion.

iv. *Aerospace betterment*: India needs to work towards low cost interplanetary missions bringing the cost of the aircraft per kg from US $20,000 per orbital to US $2000. Design development leading to building of 70 seater passenger aircraft should be made possible within 2020. This will increase the business volume to prolific US $15 billion.

v. *Providing Urban Amenities in Rural Areas (PURA):* Costs need to be highly reduced to implement 7000 PURAs all over India encompassing around 600,000 villages.

The application of electronics in the streams of Biology, Nanotechnology, Biotechnology, Aerospace and Medicine is far reaching. These converged fields have oodles of potential since they are multidisciplinary. The fields are poised for a fast, exponential growth. Research and Developmental work in this field is primarily in its nascent stages in India, unlike in the western countries as the USA or England. So in all certainties, with the government's proper disinvestment policies and apt pacts (and with no nagging political catch 22s) with allies around the globe (i.e. with proper foreign investment) the enterprising academia and industry can ameliorate India's stance on the global front. Preponderances of job opportunities and standard of living will shoot up in near future if self reliant India researchers can veer through the jutting predicaments with grit, investment, knowledge and forbearance to infuse

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