



# Upcoming Trends of Virtual Experiments for Laboratories

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## ABSTRACT

The scope of this paper includes development and implementation of virtual laboratories. Virtual Experiments can be performed using the concept of virtual Intelligent SoftLab (VIS). The virtual experiments described here will help students to perform it at anytime and anywhere. The model accepts inputs using virtual instruments and observed virtual results on the screen. There is a facility for constructing an experimental circuit, change the input values and observed outputs respectively. The graphical and simulated effects of virtual experiments are visible on the screen. SoftLab will help Electronics, Computer Science and Engineering students perform and practice experiments to improve their understanding of the subject.

## Keywords

SoftLab, Virtual, VIS Model, Virtualization, Virtual Lab.

## 1. INTRODUCTION

For the last two decades, Electronics and Computer Science technology have been among the fastest growing areas in the research field. Due to this, there is a traditional laboratory in keeping up with some of the modern industry's requirements. The concept of traditional real laboratories in educational institutions has many limitations. The availability of resources may be too limited to provide basic as well as advanced laboratory equipments, and there may be a paucity of qualified faculty members. Even if the facilities are there, in many cases a student may end up as a spectator in the conduct of experiments. Students are not free to do experiments according to their own schedules, as the time slot for an experiment may be limited to the usual working hours. Numbers of subjects like Physics and Electronics students have to perform a large number of experiments in an academic year. Many times students do not get time to repeat experiments which they have performed during the session. Also many of the laboratories lack of resources to perform experiments in which sophisticated



instruments are required. The new era of education demands a revolution and modernization in techniques for different subjects. One gap in subjects having component of practice is the lack of a complete set of e-experiments that is a full scale virtual laboratory, instead of little virtual experiments.

Science subjects always have a component of practical. In subjects like Physics and Electronics students have to perform a large number of experiments in an academic year. Many times students do not get time to repeat experiments which they have performed during the session. Also many of the laboratories lack of resources to perform experiments in which sophisticated instruments are required. Therefore to provide access to laboratory experiments, anytime anywhere, concept of virtual laboratory is developed. This virtual laboratory can cater to students at undergraduate (UG) and post graduate (PG) levels. Some software's like Mat Lab and Lab VIEW are available for simulation of experiments and for other purposes. However, these software's are generally available only in big Institutes/Laboratories and the student can use them only during college hours. It is therefore decided to develop software for performing individual experiments virtually on a computer screen. An attempt is made to develop software for electronics experiments from basic to advance level. The facilities of the laboratories in educational institutions are generally insufficient when the number of students is considered. Implementation of a laboratory to meet the requirements has a very high price.

The Virtualization of experiments is one of the most efficient ways for the modernization of traditional laboratories. Virtualization is basically the conversion of real experiments into virtual experiments with the help of information and communication technologies (ICT), which provide a real laboratory environment and 'feel' to perform the experiment. The basic goal for Virtualization is to provide a facility to perform the experiment by using either the Internet or a specific computer program. This can provide a highly interactive and powerful learning environment for the engineering and science disciplines and enables a learner to select and control all the related parameters of the experiments. A complete graphical interface with the adequate learning components and a scientific approach can provide the 'feel' of performing experiments efficiently. The Virtualization of an experiment and its application by Internet based remote techniques can provide a relevant and meaningful practical learning experience. This relatively new concept of Virtualization is cost effective and there is no time bound for the users as experiments could be accessed "24X7" anywhere any time. Virtual experiments can be used extensively for teaching, e-learning, and other computer-based education [1].



## 2. LITERATURE REVIEW

In 1990, Mercer, Lynn from Canada University of Regina proposed the concept of the Virtual Lab and built a simple one. During the next 20 years, a lot of researchers further built and enriched the concept of Virtual Lab. Experimental simulations have appeared with discipline specific texts, such as Jones and Childers (2001), and Christian and Belloni (2001), or on the World Wide Web at sites such as the *Physical Sciences Resource Center* [2]. Many of these simulations are implemented using Java applets, and are well designed and executed. Other online experimentation includes the Stevens Institute of Technology in their *Remote Dynamical Systems Laboratory* [3], which incorporated several online experiments but is subject to limited use and limited data. Mercer University has implemented the *Online Interactive Chaotic Pendulum* [4]. The site has an exemplary interface and data presentation, but doesn't provide easy access to data. Several mechanical engineering courses have online experimentation, including Curtin University [5]. These sites tend to be highly technical and their online availability appears to be limited. Other organizations that have executed online experimentation include the *Advanced Liquid Crystalline Optical Materials (ALCOM) Science and Technology Center* [6] of the Kent State University. Tan, Tang and Paterson at Queensland University of Technology had a project on developing a web based remote controlled mechanical vibrations laboratory via the Internet.

The system allowed flexibility for students to access a range of laboratory experiments at any time and any place where there is an Internet connection. Coito et al. (2007), Bauer and Fedák (2007) and Bachnak et al. (2003) discussed the ability to control and monitor processes from remote locations through a PC-based data acquisition for online and off line analyses. Advances in networking technologies and development of measurement hardware and software have turned PCs into platforms capable of continuous remote monitoring using the Internet (Fountain & Wright, 2000). Software programs that facilitate the developers of such applications are available. A user can publish data on the web with little or no programming experience. The software creates user interfaces on a *Tiwari and Singh* 673 web page to give the user access to the system (Travis, 2000). Antunes, Paulino & Piteau (1998) developed predictive methods to remotely analyze heat exchanger tube responses and wear for realistic multi-supported tubes and flow configurations. Buckman (2000) presented an introduction to the virtual instrumentation to increase the ease of use for students, and the capability to add new measurements that were otherwise unaffordable. Overstreet and Tzes (1998) describes the design and development of generic virtual instrument used for real time experimentation in the control engineering laboratory of their institute in a remote-access environment.



Salzmann (1999) proposed the steps of remote, real time control over the Internet, and demonstrated the feasibility of using a distributed online laboratory to complement and enhance the traditional laboratory. Ertugrul (2000) reported such software tool applications, and his paper aimed to provide some background knowledge about the tools and to address common problems encountered by users. Resendez and Bachnak (2003) and Bachnak et al. (2003) showed that such software tools could be used to perform data acquisition and remotely control hardware devices through the Internet. Trevelyan (2002) aimed to provide a cost effective online laboratory to staff and students. Their first project was a tele-robot, which was written in special purpose software written in C, C++ and Java. Trevelyan (2004) reviewed the entire principal lessons their group learned since 1994 and briefly described Telelabs, a cost-effective framework to provide an extendable series of online labs that could be sustained from normal operating budgets. Hofmann and Bubb (2003) explained about the virtual environment for the typical industrial application. Almgren and Cahow (2005) explained the way to make engineering education more innovative by using the Internet.

Pheatt and Ballester (2003) discussed the design and implementation of web courses and remote experiments, and the incorporation of these techniques into the curriculum without acquiring equipment, setting up equipment or creating a laboratory environment. Che (2005) presented the development of biological engineering education along with a discussion on the development of e-learning with a time sharing mainframe model and providing a centralized, remote controllable biology lab. Feisel and Rosa (2005) explored the major factors influencing conventional laboratories. They described the various limitations which affect the effectiveness of laboratory work and also its importance in science and engineering education. Ozeki et al. (2006) produced remote experiments with a digital certificate and encryption of communication data to protect a supervisory control system against illegal access. They did the development of the remote experiment system with testing and demonstration. Jeschke et al. (2008) discussed the integration of experimental setups into a virtual cooperative knowledge space, so that availability and accessibility can be enhanced for a wide range of users. They worked out the architecture and implementation of the remote experiment. Gröber, Vetter, Eckert & Jodl (2007) described a remote laboratory and its helpfulness to provide a tool to sustain this shift towards a student-centered engineering teaching approach. In papers by Bauer and Fedák (2007) and Bauer et al. (2008) a distance measurement application for educational purposes was described, and the monitoring of industrial applications was studied through web based applications. Macías and Méndez (2008) describes the automation of their



laboratory and rapid integration of automation systems into most of the engineering processes. Cui, Wang, Zhang and Akujuobi, 2011, 27 (4) (2008) focused on the reasons for traditional laboratories lagging behind and emphasize the basic demands behind the modern trend to increased virtualisation. Koliass et al. (2007) provided a categorization of remote experimentation in education according to the platform used for conducting the experiments and the scientific field represented. Gadzhonov and Nafalski (2010) reviewed the pedagogical effectiveness of distance education, with a special focus on remote laboratories for measurement and control. Machotka et al. (2010) developed the remote laboratory *NetLab* at the University of South Australia. *NetLab* was developed from the beginning as a collaborative learning environment that enables students to cooperate while conducting remote experiments via the Internet on both the domestic and international levels. Herrera and Fuller (2011) proposed a model for the implementation of remote experimentation laboratories in a distributed collaborative scenario, focusing on two crucial key elements, namely the shared knowledge and the interaction for the collaboration. They contributed towards the implementation of remote experimentation using collaborative scenarios. R Tiwari and K Singh summarized their experiences during the design, evaluation and implementation of Virtualization for a number of engineering experiments, enabling these to be accessed through the Internet as virtual experiments. They also covered the features required to give the 'feel' of performing experiments, inclusion of learning components, incorporation of easy navigation, testing of the effectiveness of learning, and development of useful feedback mechanisms.

From the geographical point of view, the educational environment can be divided into two categories called classroom environment and lab environment. The most common modern classroom environment is the multimedia classroom which includes: projectors and large screens, object display platform, DVD player and computers. Among them, the computer is increasingly becoming the center of multimedia classrooms. The virtual classroom is also called live classroom, which can provide real-time teaching function through web technology. Teachers can use text, images, handwritings, voices, videos and other forms of media to teach students with theoretical knowledge. Students can use text, voices and other forms of media to ask questions at any time. The learning process is similar to the classroom environment.

### 3. VIRTUALIZATION OF LABORATORIES

Virtualization is the creation of a virtual rather than actual version of something, such as a hardware platform, an operating system, a storage



device or a network resource. Virtualization is a technique that allows you to run more than one server (or other infrastructure component) on the same hardware [7]. The virtual machine concept was in existence since 1960s when it was first developed by IBM to provide concurrent, interactive access to a mainframe computer. Each virtual machine (VM) used to be an instance of the physical machine that gave users an illusion of accessing the physical machine directly. It was an elegant and transparent way to enable time-sharing and resource-sharing on the highly expensive hardware. Each VM was a fully protected and isolated copy of the underlying system. Users could execute, develop, and test applications without ever having to fear causing a crash to systems used by other users on the same computer. Virtualization was thus used to reduce the hardware acquisition cost and improving the productivity by letting number of users work on it simultaneously. As hardware got cheaper and multiprocessing operating systems emerged, VMs were almost extinct in the 1970s and 1980s. With the emergence of wide varieties of PC based hardware and operating systems in 1990s, the Virtualization ideas were in demand again [8]. There can be innumerable reasons how Virtualization can be useful in practical scenarios, a few of which are the following:

- **Operating System (OS) Level Virtualization:** An OS-level VM is a virtual execution environment that can be forked instantly from the base operating environment. OS-level Virtualization has been widely used to improve security, manageability and availability of today's complex software environment, with small runtime and resource overhead, and with minimal changes to the existing computing infrastructure.
- **Hardware Level Virtualization:** Hardware-level Virtualization technologies simulate the complete or a subset of hardware to run unmodified guest OS, or modify the guest OS to utilize the underlying physical hardware. Examples of the hardware-level virtualization technologies are Bochs, VMware, Virtual PC, Xen.
- **Application Virtualization:** Application Virtualization creates isolated virtual environments on a host OS to sandbox the deployment and execution of selected application programs. Such virtual environments are mainly used for four purposes: resolving application conflicts, migrating running processes, isolating untrusted programs, and supporting portable application environments.
- **Cloud Computing:** Cloud Computing is the delivery of computing as a service rather than a product, whereby shared resources, software, and information are provided with computers and other devices as a metered service over a network (typically the Internet). Cloud Computing may look like Virtualization because it appears that your application is running on a virtual server detached from any reliance or connection to a





single physical host. However, Cloud Computing can be better described as a service where Virtualization is part of a physical infrastructure. Cloud Computing builds on top of a virtualized infrastructure (compute, storage, network) by using standardization and automated delivery to provide service management. This makes monitoring the virtualized resources and the responsible deployment of these resources possible.

### 3.1 Need of Virtual Lab

Physical distances and the lack of resources make us unable to perform experiments, especially when they involve sophisticated instruments. Also, good teachers are always a scarce resource. Web-based and video-based courses address the issue of teaching to some extent. Conducting joint experiments by two participating institutions and also sharing costly resources has always been a challenge. With the present day internet and computer technologies the above limitations can no more hamper students and researchers in enhancing their skills and knowledge. In India costly instruments and equipment need to be shared with fellow researchers to the extent possible. Web enabled experiments can be designed for remote operation and viewing so as to enthuse the curiosity and innovation into students. This would help in learning basic and advanced concepts through remote experimentation. Today most equipment has a computer interface for control and data storage. It is possible to design good experiments around some of this equipment which would enhance the learning of a student. Internet-based experimentation further permits use of resources – knowledge, software, and data available on the web, apart from encouraging skillful experiments being simultaneously performed at points separated in space.

### 3.2 Objectives of the Virtual Labs

- To provide remote-access to Labs in various disciplines of Science and Engineering. These Virtual Labs would cater to students at the undergraduate level, postgraduate level as well as to research scholars.
- To enthuse students to conduct experiments by arousing their curiosity. This would help them in learning basic and advanced concepts through remote experimentation.
- To provide a complete Learning Management System around the Virtual Labs, where the students can avail the various tools for learning, including additional web-resources, video-lectures, animated demonstrations and self evaluation.
- To share costly equipment and resources, which are otherwise available to a limited number of users due to constraints on time and geographical distances?



### 3.3 Salient Features of the Virtual Lab

- Virtual Labs will provide to the students the result of an experiment by one of the following methods (or possibly a combination)
- Modeling the physical phenomenon by a set of equations and carrying out simulations to yield the result of the particular experiment. This can, at-the-best, provide an approximate version of the 'real-world' experiment.
- Providing measured data for virtual lab experiments corresponding to the data previously obtained by measurements on an actual system.
- Remotely triggering an experiment in an actual lab and providing the student the result of the experiment through the computer interface. This would entail carrying out the actual lab experiment remotely.
- Virtual Labs will be made more effective and realistic by providing additional inputs to the students like to accompany audio and video streaming of an actual lab experiment and equipment.
- For the 'touch and feel' part, the students can possibly visit an actual laboratory for a short duration.

Laboratories play an important role in engineering education. The laboratory work provides an opportunity to witness classroom-learned theoretical concepts at work; operate instruments used in the experimental set-up; measure different quantities and thereafter analyze the experimental data; and work collaboratively. However, physical distances and the lack of resources make us unable to perform experiments, especially when they involve sophisticated instruments. Also, trained teachers are always a scarce resource. Rapid development and ever increasing use of Information and Communication Technology (ICT) has revolutionized the education system by eliminating limitations in terms of physical distance, time and access, by providing equal opportunity to everyone, irrespective of place and time.

Virtual laboratories have been developed in different areas, to reproduce experiments that were made in physical laboratories. Virtual labs are useful for pre-practice and post-analysis of experiments developed in physics labs, and in some cases they can replace th

e physical lab itself. Although virtual labs may have many limitations, they have many advantages over physical labs. For example, some physical labs have a scarcity of resources (in equipment and staff), limiting the researcher's performance. Virtual labs have relatively low costs, experiments can easily be repeated, and there are no inconveniences in failing experiments, because the virtual environment is controlled, and there are no risks for natural systems. It is desirable that virtual labs exploit the advantages of virtual reality, multimedia, and the Internet. Virtual labs have





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been developed for different areas, such as physics, electronics, robotics, physiology, chemistry, engineering, economics, and ecology[9].

Develop the Soft Lab for the following purposes.

- Lower Your Measurement Costs with Virtual Instrumentation the costs of a measurement application.
- Reducing system specification time cost.
- Lowering hardware and software prices.
- Minimizing set-up and configuration time costs.
- Decreasing application software development time costs.
- Lowering system validation & hardware calibration time costs.

#### 4. EXISTING VIRTUAL LABS

An electronics student always looking for computer simulation software's to do their experiments and hobby circuits with PC thereby reducing the cost for researches for projects and laboratory works. The electronic simulation software provides a platform for design, wiring the circuits virtually and we can connect it to a number of equipments which is programmed by the software vendor with special parameters for each. So here we provide a top list of essential software that becomes handy during the course time and so on. Some of them have download links provided.

##### 4.1 IIT Virtual Labs

An Initiative of Ministry of Human Resource Development (MHRD) Under the National Mission on Education through ICT design in IIT Delhi, Bombay, Kanpur, Kharagpur, Madras, Guwahati and all its participating Institutes. IIT design the virtual lab for Electronics and communication, Computer Science and Engineering, Electronic Engineering, Mechanical Engineering. This system is more advanced for the Engineering faculty [10].

##### 4.2 LabVIEW

**LabVIEW** (short for Laboratory Virtual Instrumentation Engineering Workbench) is a system design platform and development environment for a visual programming language from National Instruments. LabVIEW is a software development environment originally designed for computer-controlled data acquisition. It has since grown to be a general purpose programming environment with a wide range of applications. The basic object in LabVIEW is a Virtual Instrument (VI). It has two parts:

- The Front Panel or GUI.
- The Block Diagram or programming guts.

The VI Front Panel was originally designed to mimic the front panel of a laboratory instrument, but it can be set up to resemble pretty much any sort



of user interface. National Instruments has a website entitled LabVIEW 101 that contains a series of instructional videos and PDFs of the instructions. LabVIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of platforms including Microsoft Windows, various versions of UNIX, Linux. The latest version of LabVIEW is version LabVIEW 2011, released in August 2011. In LabVIEW 8.20, you have the freedom to choose your preferred syntax for technical computing. Whether developing algorithms, analyzing results, processing signals, or exploring DSP concepts, you can combine the intuitive LabVIEW graphical dataflow programming with LabVIEW MathScript, a math-oriented text-based programming language that includes more than 600 commonly used functions for math, signal processing and analysis [11].

### 4.3 Circuit Maker

Circuit maker is a simple, powerful schematic capture and downloading tools. It is most useful for a normal user to design and simulate his various circuits using circuit maker [12].

### 4.4 Digital Works

Digital works is a simple graphical design tool to construct various digital electronic circuits and virtually simulates to analyze their behavior through real time simulation [13].

### 4.5 MATLAB

**MATLAB (matrix laboratory)** is a numerical computing environment and fourth generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of function and data, implementation of algorithms creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and FORTRAN. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems [14].

### 4.6 The Laboratory Web Site

A lab website is developed using *Google Sites* for local as well as remote students. General lab safety and radiation safety information are made available. Instructions to use Skype and the web cameras are also on the lab website. In addition, the website includes separate links for all of the experiments in NPPE 451 and provides references and links of relevant information about each experiment. The course outline and the handout for each experiment are also available. Video recording of the lecture for each



experiment can also be made available. A frequently asked question (FAQs) section is continuously being developed for each experiment.

#### **4.7 Virtual Labs**

The laboratory consists of eight experiments ranging from introducing the student how to use the equipment to build a resonant circuit and active filters. The computer-based laboratory was created to duplicate an actual electronics laboratory that has been given for many years at Vanderbilt University as an initial practical experience with electrical circuits. The computer environment created consists of a high fidelity simulation of the physical environment embedded in a computer-structured copy of the original, physical laboratory curriculum. After an introductory tour of the laboratory procedure, the student can elect to work the first laboratory or to go through a step-by-step tutorial. Tutorials are implemented for the components (i.e., resistor, capacitor, and inductor) and the instruments (breadboard, function generator, and oscilloscope). The component tutorials provide very basic information on how to select component values. In the case of resistors, after completing the tutorial, the student is asked to identify the specific value of a resistor from its color code. For the function generator and oscilloscope, the tutorial provides the name, location, and function of each control and indicator for both instruments [15].

### **5. VIRTUAL INTELLIGENT SOFTLAB**

Electronic devices and the lack of resources make us unable to perform experiments, especially when they involve sophisticated instruments. Web-based and video-based courses address the issue of teaching to some extent. Conducting joint experiments by two participating institutions and also sharing costly resources has always been a challenge. With the present day internet and computer technologies the above limitations can no more hamper students and researchers in enhancing their skills and knowledge.

The SoftLab philosophy challenges us to link the physical laboratory experiment with its theoretical simulation model within a unified and interactive environment. The goal for each instance of a SoftLab laboratory is to create a software environment where experimental research, simulation and education coexist and interact with each other. As part of the SoftLab project, we are investigating the issues involved in the design and development of the SoftLab Model for Electronics, Computer science and engineering. The VIS describes how the SoftLab philosophy has used to design and implements.

The Virtual SoftLab forces us to address the challenge of solving experiments. Such systems require a wide range of expertise plus a flexible



and diverse array of equipment. The SoftLab framework should provide the infrastructure and facilities that serve the needs of basic research.

The basic facilities include with VIS:

- High-performance graphics processors to support scientific visualization, and multimedia facilities.
- Software that allows application researchers to make full use of these facilities to evaluate their experiments without any risk.
- Virtual laboratories that provide scientists with a full range of functionality, both for experimental activities and for the mathematical modeling and simulation of the experimental processes.

The laboratory presents an ideal environment in which to accept and meet the challenges of computational science and engineering. Issues that must be addressed include mathematical software, electronic prototyping, geometric modeling, parallel algorithms, databases, software engineering, and computer systems. This facility is the use of research in electronics, computer science and engineering Department.

In order to support the various activities that take place in a physical laboratory, scientists must be able to use the virtual laboratory -

- To perform physical experiments by interacting with and controlling remote instruments.
- To simulate physical experiments through computer modeling of the experimental process.
- To compare physical and simulated data by playing back recorded experiments.
- To train scientists to understand the physical experiment, the computational model of the experiment, and the relationships between them.

Virtual SoftLab can benefit thousands of students and professors to learn difficult experiments. The “Virtual laboratory” will bridge physical distance and availability of resources. Today it is possible to design good experiments among students for better learning. Virtual Labs would helpful to students at the graduate level, postgraduate level as well as to research scholars. This would help them in learning basic and advanced concepts through Virtual Intelligent SoftLab (VIS) experimentation. This system provides a complete Learning Management system around the virtual Labs where the students can learn, observe and research the various tools. Video-lectures, animated demonstrations and self evaluation program available in future. This system also shares costly equipment and resources with visual effects. This relatively new concept of Virtualization is cost effective and there is no time bound for the users as experiments could be accessed "24 x 7". Virtual experiments can be used extensively for teaching, clearing, and



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other computer-based education. The functionality provided by this problem solving environment will therefore be:

- Collect the experimental data in real time.
- Provide a visualization of the experiments.
- Control the experiment.
- Input the experimental data to the computational model.
- Control the computational model and visualize the numerical simulation solution.

Professionals confirmed certain characteristics of the virtual lab.

- Creating new intellectual models in education better than the real, and more beautiful than the imagination.
- Knowledge-building and inculcate information.
- Encouraging and guiding students.
- Registering students' information and evaluating them automatically.
- Performing experiments, which are difficult to be performed in the traditional lab due to its danger and high cost.
- Reducing the learning time spent in the traditional lab.
- Develop an exploration based on scientific assumptions and processes.
- Permanently updated.

## 6. CONCLUSIONS

SoftLab will help Electronics; Computer Science and Engineering students perform and practice experiments to improve their understanding of the subject. The design of the VIS model is more effective and realistic as necessary variable inputs and outputs are visible on the monitor screen. This model created for the client based system, can be converted into a client - server based application system. Through this model, the examiner can conduct the examination, in which the student can perform their experiments in a given time period, by applying timer. Some modifications may be done, by applying a video camera. Through this video camera, the lab instructor or examiner can watch the video clip of the experiment performed by the student in stepwise so that the instructor/examiner can find the errors if any. This virtual experiment provides practice for students for the 'touch & feel' part they have already performed in the laboratory.

## 7. ACKNOWLEDGEMENTS

We are very much thankful to Dr. D. A. Deshpande, Dr. P. K. Butay and Dr. U. A. Lanjewar for their valuable inputs, constant guidance and their extensive support and encouragement in this work.



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