INTRODUCTION

With computing devices becoming smaller and smaller it is now possible for an individual to don such a device like a hat or jacket. It is clear that these technology will enable us to extent the desktop resources(including memory computation and communication) to anywhere in travel. Also this constant access, augmented by a battery of body mounted sensors will enable a computer to be sensitive to the activities in which we are engaged and thus allow the computer to participate in an active manner as we perform our tasks. This area includes computer science, computer engineering and psychology.

Other than being a portable computer, a wearable computer must be an adaptive system with an independent processor. That is the system must adapt to the whims and fancies of the user instead of the user having to adapt his lifestyle for the system. The system must be perpetually on and must provide seamless information transfer whenever the user requires it.
HISTORY

The concept of wearable computing was first brought forward by Steve Mann, who, with his invention of the ‘WearComp’ in 1979 created a pioneering effort in wearable computing. Although the effort was great, one of the major disadvantages was the fact that it was nothing more than a miniature PC. Absence of lightweight, rugged and fast processors and display devices was another drawback.

The 1980s brought forward the development of the consumer camcorder, miniature CRTs etc. brought forward the development of the eyeglass mounted multimedia computer. With the advent of the internet and wireless networking technologies, wearable devices have developed a great deal.

After its invention wearables have gone through 18 generations of development, with research going on at prestigious institutions like MIT, Georgia Tech and Carnegie Mellon University.

The six devices to be introduced represent the new frontiers in the development of wearable technology. They are:

1. Nomad – Wearable Audio Computing
2. DyPERS – Dynamic Personal Enhanced Reality System
3. Wearable Cinema
4. Affective Computers
5. FAST – Wearable Computing for Factory Personnel
6. Computerized Clothing
NOMAD – WEARABLE AUDIO COMPUTING

The Nomadic Radio provides an audio only wearable interface and acts as a unified messaging system. Remote information such as email, voicemail, hourly news broadcasts, reminders, traffic reports etc are automatically downloaded and presented to the user in a seamless manner. The presentation is such that it produces minimum disturbance to the user.

Objective

In the present day, when unlimited information is made available to the user through various media, it is found increasingly that the user suffers from information overload. That is, unwanted information is being provided to the user and this causes less stress being placed on the required information. E.g. Spam mails in our inbox. Moreover the user is not able to access the information at all times.

Pagers and Cellular phones provide mobility to a large extent, but the information that can be transmitted through a pager is very limited and cellular phone services are expensive as all the data processing is done by the telephony servers rather than by the phone itself.

The Nomad filters information and provides adaptive notification, messaging and communication services on a wearable device. The system determines the method of presentation of the information based on the time of the day, physical position, scheduled tasks, message content, and level of interruption and acoustics of the environment. The user's long term listening patterns will also be taken into consideration.
Nomadic Radio is developed as a unified messaging system which utilizes spatialized audio, speech synthesis and recognition on a wearable audio platform. The system mainly works on a client server model. A combination of speech and button inputs allow the user unlimited access to the information he wants. Text messages such as email; reminders etc are converted to voice using a synthesizer. Users can select from the various categories of information available, browse the messages and save or delete from the server. As the system gains location awareness, a scenario is envisaged where the information is presented depending on the location of the user.

**Design of the Wearable Platform**

Audio output must be provided such that it causes minimum hindrance and maximum privacy to the user. Headphones cannot be used as it would be a nuisance for obvious reasons. Thus speakers worn on the body were developed.
The Soundbeam Neckset worn around the neck consists of two directional speakers provided on the user’s shoulders and a directional microphone placed on the user’s chest. A button is provided to activate speech recognition. Spatialized audio is provided in the neckset. A rugged version of the neckset is the Radio Vest which consists of four directional speakers, a rugged housing and modular configuration.

**Network Architecture**

The nomadic radio consists of a client server model and works over a wireless LAN. The Neckset is connected to a Pentium based portable processor connected to the waist. The web servers download information such as: emails and voicemails from the user’s mailbox, reminders, hourly news broadcasts, and weather and traffic reports. The web server filters the information and removes unwanted information. The user, when notified can download the information.
from the web server to the radio and listen to it in the required format.
The network also consists if a position server whereby the position of
the user can be determined using an IR sensor.

**Working with the Device**

The information must be provided to the user in such a manner
that it causes minimum disturbance to the user. One of the methods
used by the Nomad is to broadcast the news, reports etc in the
background. The Audiostreamer device checks for Head Related
Transfer Functions (HRTF), i.e. whether the user is straining his head
to listen to the news. If so, the volume of the broadcast is increased.
Spatialized listening is provided for the voicemails and emails which
arrive at different times of the day. The audio is arranged in such a
way that the sound arrives from different directions for mails arriving at
different times of the day. The device mainly works in 3 modes of
operation:

**Broadcasting**

In this mode, messages are broadcast to the user at low tones,
in the background. If the user pays attention to the message (by
button press or HRTF), the message is brought to the foreground,
else it is faded away.

**Browsing**

In this mode the user selects the category and plays back the
messages sequentially. When a required message is received, the
user can stop the device and listen to the message in the foreground.
Scanning

In this mode, certain portions of the message are played sequentially each message coming to the foreground for sometime and then fading out as the new message enters the foreground. The user selects the message as it comes to the foreground.

Awareness & Communication

The Nomad allows the user to be aware of the location of other users and determine their location using the position sensor. The user can also chat with other users from a remote location using the Nomad network.
DyPERS

Introduction

As computation becomes faster and easier, human capabilities like daily scheduling like planning, scheduling etc can be performed by personal digital assistants (PDAs). But transfer of this information from the real world to the PDAs requires tremendous effort from the user. Thus this transfer of information must be provided in a natural seamless manner. For this we use DyPERS – Dynamic Personal Enhanced Reality System.

The device acts as an audio-visual memory assistant which reminds the user at appropriate times using perceptual cues. The DyPERS stores relevant information from what the user sees using a portable camera. This audio visual clip is stored along with the required index in the memory of the system. Whenever the device encounters the device again in its field of vision, the system plays back the clip through a Heads up Display (HUD).

Audio-Visual Associative Memory System

The main principle of operation of DyPERS is called Record & Associate. In this system, the user records relevant video clips using the camera mounted on the line of sight of the user. After recording he associates the recorded clip to an object which acts as the index to the clip. The device then scans for the indexed image and if it ‘sees’ a similar object, it is sent to the processor which compares it with the original index and returns a ‘confidence level’. If the confidence level is above a certain threshold level, the video clip is played back on the HUD by the system.
Working

The audio-visual recording module accumulates buffers containing audio-visual data. These circular buffers contain the past 2 seconds of compressed audio and video. Whenever the user decides to record the current interaction, the system stores the data until the user signals the recording to stop. The user moves his head mounted video camera and microphone to specifically target and shoot the footage required. Thus, an audio-video clip is formed. After recording such a clip, the user selects the object that should trigger the clip’s playback. This is done by directing the camera towards an object of interest and triggering the unit (i.e. pressing a button). The system then instructs the vision module to add the captured image to its database of objects and associate the object’s label to the most recently recorded A/V clip. The user can select from a record button, an associate button and a garbage button. The record button stores the A/V sequence. The associate button merely makes a connection between the currently viewed visual object and the previously recorded sequence. The garbage button associates the current visual object with a NULL sequence indicating that it should not trigger any playback. This helps resolve errors or ambiguities in the vision system.
Whenever the user is not recording, the system continuously scans its field of view to check whether any of the objects in its database are present. If so the video clip is played back as instructed. The recording, association and retrieval are presented in a continuous manner.

Object Recognition System

In order to recognize an object, multidimensional histograms of the object image are taken and is compared with the histograms of the images in the database of the system. Similar histograms were considered as a positive recognition. In order to test whether such a system would work, an experiment was conducted in which 103 similar objects were scanned at different image plane rotations and views points.

Hardware

At present, data transmission is via wireless radio communications, which makes mobility of the user, limited. In the future better data transmission methods could be evolved. The main components of the DyPERS system are shown:
The HUD is a Sony Glasstron display with semi-transparent display and headphones. A video camera with wide eye lens is used to increase field of vision and is mounted near the user’s forehead to remain in the line of sight. The A/V data captured by the camera is transmitted using a wireless radio transmitter to a workstation. Here the captured video is split into image clips and compared to various images in its database. The required data is then transmitted back to the user. The clips are then displayed on the Glasstron HUD. Two A/V channels are used at all times to transfer data bidirectionally.

Applications

The applications of such a device are tremendous. Some of them are:
- Daily scheduling can be stored easily and associated with a personal trigger object.
- An important conversation can be recorded and associated with the person’s visiting card.
- Online instructions could be provided for an assembly task.
- The device could be used for crime prevention by recognizing the criminal by comparing with earlier records.
WEARABLE CINEMA

Introduction

Application in Museum Environment:

Over many years, the concept of interactive cinema has been experimented with, without much success. With the advent of wearable computing, this concept might be a reality. Researchers sat the MIT Media Lab have developed a new way whereby interactive cinema can be displayed to the wearer, using visual cues from the environment.

The experimentation was performed in a museum environment. Interactive documentaries and explanations on each exhibit had to be shown to the visitor to give him an enhanced experience. The introductory presentation must not divert the viewer’s attention away from the exhibit. The wearable cinema offers to fuse together the documentary and the visitor’s path in the exhibit using a wearable computer.

A perceptive media modeling of the content unfolds the wearable cinema as the visitor walks around the space, and the camera attached to the wearable recognizes its presence in specific locations or relevant objects.

The Wearable Cinema system allows recording small chunks of video and associates them with triggering objects. When the objects are seen again at a later moment, the video is played back. Wearable Cinema is not a simulation running on a desktop computer connected to a head mounted display. It actually runs on a wearable, which was especially designed for it, and the computer vision runs in real time on the wearable CPU.
The main distinctive characteristic of this setup is that it uses real time computer vision as input for easier and faster location finding. The system uses DyPERS technology to recognize objects in its field of vision. A quick training on the locations or objects to recognize is the only setup needed for the computer vision system at start. The wearable is made by two sandwiched CPUs. One is dedicated to processing the input and the other to produce the output shown on the wearable display. These two very thin and lightweight computers are hosted inside a stylized backpack. The wearable is connected to a small wide-angle camera worn on the user's shoulder, and to a high resolution SVGA display.

**Working**

Once the training is over, the system is ready to be used. Initially the first CPU and camera is used to recognize the object. As the viewer comes near an exhibit, the image of the exhibit is captured by the camera and its histogram is compared with the indexes in its database. Once the information has been obtained, the CPU gives the contacts the next system which stores all the documentaries. The required documentary is selected and played back on an augmented reality display to enhance the viewer experience.
AFFECTIVE COMPUTING

An “affective wearable” is a wearable system equipped with sensors and tools which enables recognition of its wearer's affective patterns. Affective patterns include expressions of emotion such as a joyful smile, an angry gesture, a strained voice or a change in autonomic nervous system activity such as accelerated heart rate or increasing skin conductivity. Affective Wearables are similar to medical wearables as both sense physiological signals.

One of the biggest problems in emotion theory is determining the physiological patterns accompanying each emotion. These signals could vary depending on the individual. This limits the application of affective computers to a great deal.

Applications

In the modern world when people have less time to care about their health, affective signals give crucial information on anxiety, depression etc which have been shown to affect the work of the immune system, slowing down healing and making people more vulnerable to viral infections. Thus the wearer can make informed decisions and can be shared with a physician. It can also be used in treating chronic problems like back pain, migraine etc which can be stress related.
In addition to medical applications, affective wearables function as effective memory managers. Emotions are known to provide a keen index into human memory. So a computer that pays attention to your emotional state will know what you are likely to remember. This is useful to people dealing with information overload.

One of the recently developed devices which work on the principles of Affective Computing is the Startle Cam – being developed at the media lab at MIT.

**Startle Cam**

**How it works**

The Startle Cam is a wearable video recording mechanism which responds to a 'startle' by the wearer. The cam consists of a camera worn as a pendant around the wearer's neck, together with skin conductivity sensors and pattern recognition software. The camera continuously records and stores in a buffer, deleting the oldest images as the buffer is filled. Simultaneously, the system uses small electrodes on the wearer's skin. The pattern recognition software recognizes the wearer's startle response. The startle is selected as this emotion is fairly robust and easy to detect. Images are stored in a virtual buffer until the detection algorithm of the Startle Cam is detected.

When the startle is detected, the images extracted from the buffer can be saved in the permanent memory for later use. The images are saved as a single image and is either saved to the hard drive or sent over the internet to a remote server.
By saving the information when a startle is detected, the system substitutes for the human ‘flash memory’, whereby extremely arousing events are stored with clarity in one’s mind. The camera can also be used in the opposite sense – to record those details one might have missed while the mind was idle.

The StartleCam system consists of a skin conductivity sensor (GSR) which is sampled by an analog to digital converter attached to a wearable computer. A digital camera and digital modem are also attached to the computer. Images are captured by the digital camera and stored in a buffer in memory. When the computer algorithm detects a startle response, the buffer of images is downloaded and transmitted wirelessly back to the Internet. Figure (a) shows the details of the system and Figure (b) shows the system as worn with skin conductivity sensors on the hand can be placed on the fingers.
FAST – WEARABLE COMPUTING FOR FACTORY PERSONNEL

Introduction

Factories and workplaces today are being more and more automated. The machines being used in these environments are being more complex and difficult to perceive. In the present setup, it is necessary for the worker in the factory to know the working of the device and how to repair it in case of faults. For this purpose, organizations provide training to the employees. But the various disadvantages of training are:

Training is costly and time-consuming. Training takes employees off the job and sometimes requires employees to travel to a different location.

Training is not immediate. Training is often forgotten by the time it is finally needed on the job. Also, since a lot of training is not performed in the context of the job, it is difficult for employees to transfer what they are learning in training to the actual job that they do at work.

Training is geared towards increasing knowledge as opposed to increasing productivity. Since the true business goal of training is to improve the productivity of the work force, training is currently not directly serving this goal.

Training is trainer-centered as opposed to learner-centered. The trainer decides what the employee should know as opposed to the employee asking for the information that the employee needs to get the job done.
Training is evaluated on learner satisfaction and attainment of classroom goals instead of job performance. Good job performance is the true goal of training.

It is in such situations that performance support systems like FAST are used. These devices train the employees on the job. This is a major shift in the way training is currently conducted.

**FAST Performance Support System**

Factory Automation Support Technology (FAST) is a new project for Georgia Tech researchers. FAST is intended to: 1) train employees as they perform their jobs, rather than before they perform their jobs, and 2) meet the needs of today's mobile work force.

**Hardware**

Fast hardware consists of a wearable voice activated computer system. The system is basically an Intel 486 computer with 24 MB RAM, 340 MB hard disk and wireless network adapter. Nickel metal hydride battery packs are used as power supply. The system works on Windows 95, UNIX or DOS operating systems.
The main components of the system are:

A see-through display allows the user to work while looking at text, drawings, and video that is pertinent to the user's job.

A wireless communications link sends and receives up-to-date information to and from the plant computer system.

A wearable computer allows the user to enter and receive information wherever the user goes

A battery pack to supply power for all the components

This computer system enables employees to get information at the task site and, since their hands are not busy operating the computer, to continue to perform a task as they are receiving the information. This wearable computer system complements software-based performance support systems by making them accessible to employees at all times and in all places during their work day.

**Software**

The main information provided by the FAST System to the trainee is:

- Just-in-time, task-specific training
- Expert advice about a job task
- Step-by-step procedures
- Data collection forms for inspection tasks
- A database of past problems and resolutions
- Communication links for remote collaboration with experts
The main menu on the head mounted display includes the following:

- A brief description of the task goal
- The steps to follow to meet the goal
- A tool that helps the user correct his or her work.
- An on-line library of background information.

A typical interaction consists of several steps. Any step is begun by speaking into the headset any word or combination of words visible on the screen. The system then recognizes the spoken phrase and calls up the requested information automatically. If for some reason the user does not wish to speak the command, a pointing device may be used instead to select an item by clicking on the desired button. Any visible words on buttons are possible commands. The user continues to navigate through the system using voice commands and may occasionally be required to enter some data as well. In the section that has step-by-step instructions, each step begins with a simple static drawing and auditory instructions. To understand the intricacies described by the step, the user can examine the drawing for as long as desired. Since the display does not block the user’s field of view, the user can look at the drawings, listen to the auditory instructions, or view an explanatory video while completing the prescribed task.

**Advantages of using FAST**

Preliminary studies conducted by Carnegie Mellon University in conjunction with maintenance of heavy vehicles point the way to significant advantages including:

- 1000 to 1 reduction in the weight of the documentation in electronic form vs. paper
2 to 1 reduction in the number of personnel required to perform an inspection task

40% reduction in time required to perform an inspection procedure

30% reduction in post processing time of collected data.

**Advances of FAST Technology**

The next generation of FAST computers will use networking technology, whereby video capture devices will be connected to a wearable computer and the device is networked with the main system so that a technician can send live video and audio of the equipment to a remote expert. The expert can then communicate to the technician through video and come with a solution.
COMPUTERIZED CLOTHING

There is a major movement towards the development of the next generation of wearable computers – being called as the post PC era. With this fast developing technology, computers and other electronic devices will be able to be directly integrated into our clothing, so that they are virtually invisible. Computerized Clothes will be the next step in making computers and devices portable without having to strap electronic gadgets onto our bodies.

The Fabric

Cotton, polyester or rayon don't have the needed properties to carry the electrical current needed for digital clothing. Researchers at MIT's Media Lab are using silk organza, a unique fabric that has been used to make clothes in India for at least a century.

A micrograph of silk organza.

The copper foil that is wrapped around the horizontal threads can be seen.

Silk organza is ideal for computerized clothing because it is made with two fibers that make it conducive to electricity. The first
fiber is just an ordinary silk thread, but running in the opposite
direction of the fiber is silk thread that is wrapped in a thin copper foil.
It's this copper foil that gives silk organza the ability to conduct
electricity. Copper is a very good conductor of electricity and some
microprocessor manufacturers are beginning to use copper to speed
up microprocessors.

Not only is silk organza a good electrical conductor, but it's
fiber's are spaced with the right amount of space, so that the fibers
can be individually addressed. A strip of the fabric would basically
function like a ribbon cable. Ribbon cables are used in computers to
connect disk drives to controllers. One problem with using silk
organza would result if the circuits were to touch each other, therefore
MIT scientists use an insulating material to coat or support the fabric.
Once the fabric is cut into a desirable shape, other components need
to be attached to the fabric, like resistors, capacitors and coils. These
components are sewn directly to the fabric. Additional components,
such as LEDs, crystals, piezo transducers and other surface mount
components, if needed, are soldered directly onto the metallic yarn,
which the developers say is an easy process. Other electronic devices
can be snapped into the fabric by using some kind of gripper snaps,
which pierce the yarn to create an electrical contact. These devices
can then be easily removed in order to clean the fabric.

GTWM

Research on the design and development of a Smart Shirt for
Combat Casualty Care has led to the realization of the world's first
Wearable Motherboard or an "intelligent" garment for the 21st
Century. The Georgia Tech Wearable Motherboard uses optical fibers
to detect bullet wounds, and special sensors and interconnects to
monitor the body vital signs during combat conditions. This Georgia Tech Wearable Motherboard (Smart Shirt) provides an extremely versatile framework for the incorporation of sensing, monitoring and information processing devices. The principal advantage of Smart Shirt is that it provides, for the first time, a very systematic way of monitoring the vital signs of humans in an unobtrusive manner.

**Requirement:**

Casualties are associated with combat and sometimes are inevitable. Since medical resources are limited in a combat scenario, there is a critical need to make optimum use of the available resources to minimize such casualties. Therefore, any effort to minimize the loss of human life has a value that is priceless. In a significant departure from the past, the loss of even a single soldier in a war can alter the nation’s engagement strategy making it all the more important to save lives.

Similarly, on the civilian side, the population is aging and the cost of healthcare delivery is expected to increase at a rate faster than it is today. With the decreasing number of doctors in rural areas, the doctor/patient ratio is, in certain instances, reaching unacceptable levels for ensuring a basic sense of comfort for people living in such areas. Patients discharged after major surgeries typically experience a loss of sense of security when they leave the hospital because they feel "cut off" from the continuous watch and care they received in the hospital. This degree of uncertainty can greatly influence their post-operative recovery. Therefore, there is a need to continuously monitor such patients and give them the added peace of mind so that the positive psychological impact will speed up the recovery process. Mentally ill patients need to be monitored on a regular basis to gain a
better understanding of the relationship between their vital signs and their behavioral patterns so that their treatments can be suitably modified. Such medical monitoring of individuals is critical for the successful practice of telemedicine that is becoming economically viable in the context of advancements in computing and telecommunications. Likewise, continuous monitoring of astronauts in space, of athletes during practice sessions and in competition, of law enforcement personnel and combat soldiers in the line of duty are all extremely important.

The GTWM was woven into a single-piece garment (an undershirt) on a weaving machine to fit a 38-40" chest. The plastic optical fiber (POF) is spirally integrated into the structure during the fabric production process without any discontinuities at the armhole or the seams using a novel modification in the weaving process.

An interconnection technology was developed to transmit information from (and to) sensors mounted at any location on the body thus creating a flexible "bus" structure. T-Connectors -- similar to "button clips" used in clothing -- are attached to the fibers that serve as a data bus to carry the information from the sensors (e.g., EKG sensors) on the body. The sensors will plug into these connectors and...
at the other end similar T-Connectors will be used to transmit the information to monitoring equipment or DARPA's (Defense Advanced Research Projects Agency) personal status monitor. By making the sensors detachable from the garment, the versatility of the Georgia Tech Smart Shirt has been significantly enhanced. Since shapes and sizes of humans will be different, sensors can be positioned on the right locations for all users and without any constraints being imposed by the Smart Shirt. In essence, the Georgia Tech Smart Shirt can be truly "customized." Moreover, the Smart Shirt can be laundered without any damage to the sensors themselves.

The interconnection technology has been used to integrate sensors for monitoring the following vital signs: temperature, heart rate and respiration rate. In addition, a microphone has been attached to transmit the wearer’s voice data to monitoring locations. Other sensors can be easily integrated into the structure.

**Using the GTWM**

A combat soldier attaches sensors to his body, pulls the Smart Shirt on, and attaches the sensors to the Smart Shirt. The Smart Shirt functions like a motherboard, with plastic optical fibers and other specialty fibers woven throughout the actual fabric of the shirt. To pinpoint the exact location of a bullet penetration, a 'signal' is sent from one end of the plastic optical fiber to a receiver at the other end. The emitter and the receiver are connected to a Personal Status Monitor (PSM) worn at hip-level by the soldier. If the light from the emitter does not reach the receiver inside the PSM, it signifies that the Smart Shirt has been penetrated (i.e., the soldier has been shot). The signal bounces back to the PSM from the point of penetration, helping the medical personnel pinpoint the exact location of the soldier’s wound.
The soldier's vital signs—heart rate, temperature, respiration rate, etc. are monitored in two ways: through the sensors integrated into the T-shirt; and through the sensors on the soldier's body, both of which are connected to the PSM. Information on the wound and the soldier's condition is immediately transmitted electronically from the PSM to a medical triage unit somewhere near the battlefield. The triage unit then dispatches the appropriate medical personnel to the scene. The Georgia Tech Smart Shirt can help a physician determine the extent of a soldier's injuries based on the strength of his heartbeat and respiratory rate. This information is vital for assessing who needs assistance first during the so-called 'golden hour' in which there are numerous casualties.
CONCLUSION

Wearable Computer has come a long way from the days of the WearComp. Extensive research and development work at various centers have ensured that these wonderful devices will change our lives dramatically in the near future. Several commercial vendors have started manufacturing and marketing these devices.

The earlier devices were quite obtrusive and often made the wearer ill at ease, but recently, such devices have been gaining social acceptance. This is attributed partly to miniaturization and partly to dramatic changes in people’s attitude to personal electronics. This factor will soon disappear as the apparatus disappears into ordinary clothing and eyeglasses. Clothing based computing with personal imaging will blur all boundaries between seeing and viewing and between remembering and recording. Rather than living within our own personal information domain, networking will enlarge our scope through shared visual memory which enables us to “remember something we have never seen.

With computers as close as shirts on our backs, interaction will become more natural. This will improve the ability to do traditional computing whiling standing or walking.

Within the next few years, we can expect entirely new modes of human – computer interaction to arise. Wearable Computers will help in the development of a cyborg – a system in which the camaraderie between a human and machine becomes seamlessly simple. This will bring forward a new set of technical, scientific and social needs which will have to be addressed as we take the first step towards coexisting with wearable computers.
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ACKNOWLEDGEMENT

I express my sincere thanks to Prof. M.N Agnisarman Namboothiri (Head of the Department, Computer Science and Engineering, MESCE), Mr. Zainul Abid (Staff incharge) for their kind co-operation for presenting the seminar.

I also extend my sincere thanks to all other members of the faculty of Computer Science and Engineering Department and my friends for their co-operation and encouragement.

Shabeel P.V
ABSTRACT

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The six devices to be introduced represent the new frontiers in the development of wearable technology. They are:

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