MECHATRONICS ASSISTED ARCHICTETURE

Thomas Bock
Technische Universität München, Munich
thomas.bock@bri.ar.tum.de

Pranav Kishore
Malaviya National Institute of Technology Jaipur, Jaipur, India
pk06uar@mnit.ac.in

Thomas Linner
Technische Universität München, Munich
thomas.linner@bri.ar.tum.de

Willi Viktor Lauer
Technische Universität München, Munich
Willi.Lauer@bri.ar.tum.de

Abstract
This article will be giving an overview about the technological structure of the futuristic home environments which are basically a combinations of smart environments, sustainable environments, communicable environments, Artificial Intelligence, in cooperation with mechatronic systems. These futuristic environments can be considered as a solution for the expected problems like energy crisis, healthcare & wellness of the human beings in their home environment. The introduction of sensors and comunication technologies can be seen as a platform or base towards the implementation of intelligent and interacting systems, such as service and maintenance robots.

KEYWORDS: Home environment, Service Robotics, Smart Home, Sustainability, Mechatronic Systems

INTRODUCTION

As we all know that in the recent past, there has been observed significant changes in the social life, ecological cycles, dependence of life on technologies, etc. of our surroundings. This issue has given birth to the several problems, but through this paper, we are trying to find the solution for the fact that how these changes are going to affect Futuristic Home Environments in order to make comfortable living and habitat for the human beings.

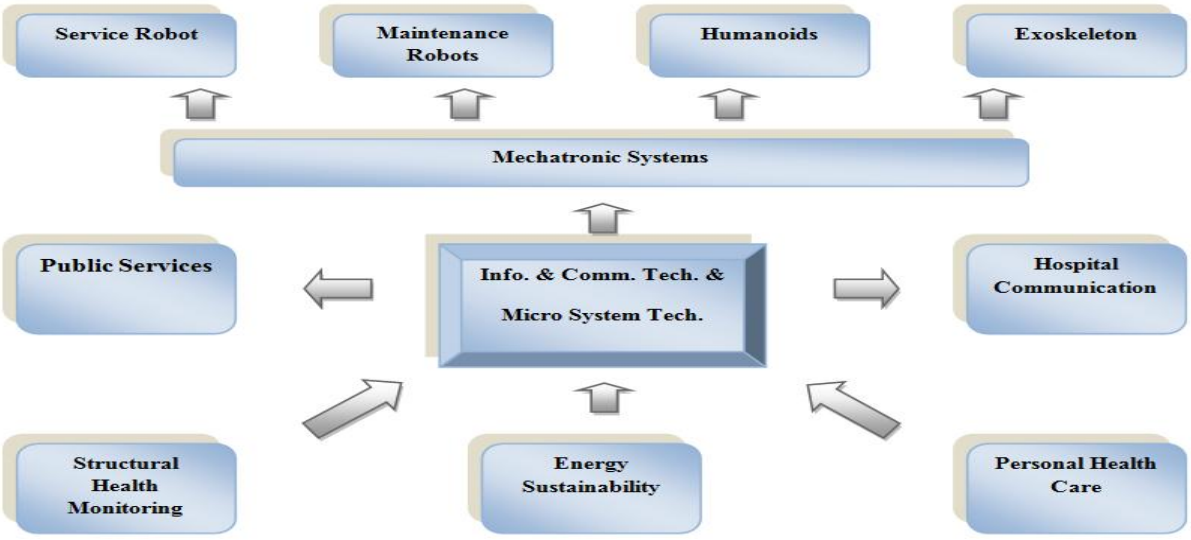

Figure 1: Technological Hierarchy for Futuristic Home Environment

On the basis of the studies made in this area, it has been found that few of the most expected and increasing problem for the coming future are Energy Crisis, Healthcare and Technology management for the elderly and patients life. So, we derived a hierarchy chart (See Figure 1), which declares that we need a combination of Communication technologies with automated healthcare & wellness technologies, Sustainable Technologies and Home Health Monitoring Technologies which can be simultaneously used in the real time domain by Hospitals and Public Services to reduce the day to day life complexities. And then It can be further transferred to appropriate mechatronic systems for getting the things done like Service Robots, Cleaning Robots, Humanoids and exoskeleton.

RESEARCH METHODOLOGY

In this paper we have made the studies of different relevant technologies for the built environment of home on certain parameters in every classification area which has been shown in Figure 2.

Technical Classification Category	Name	Performance	Short Description	Components (sensors& actuators)	Locations	Cost Effectiveness	Size, Dimension and weight	Readiness	Integrating Components

Figure 2: Research methodology format

We have selected the parameters in such a way that by going through those parameters, an overview can easily be made about that particular technologies like performance, brief description, details of the sensors and actuators (if involved), location inside the house, cost, size, dimensions and weights, readiness and integrating units like walls, ceilings, floors. But in Table 2 and Table 6, we have used the very same parameters for finding out the most efficient technologies in the similar ranges.

CLASSIFICATION AND EVALUATION OF TECHNOLOGIES FOR THE FUTURE HOME ENVIRONMENT

Communication Technology

As we know that communication is basically the process of transfer or exchange of information from one entity to another, therefore we have decided that all of the technologies which can be used for imparting or interchange of thoughts, opinions or information by speech, writing or signs either in one way or in both ways should be classified as Communication Technology. By '*one way*' Communication Technologies we refer to those technologies which are meant for 'information and learning' and by 'both way' we refer to those technologies which are meant for 'social interactions'. It can be observed that here we have discussed about three of the Communication Technologies which can be installed in the built environment of the home, namely 3D projection systems, 3G wireless technologies and portable projection systems (see Table 1).

Table 1: Details of communication technologies for smart home environment

Technical Classification Category	Name	Performance	Short Description	Components (sensors& actuators)	Locations	Cost Effectiveness	Size, Dimension and weight	Readiness	Integrating Components
Communication (social interaction, Information or learning)	3D Projection systems	Efficiently works for information and learning.	Resolution- (1280x720)or (1024x768)@ 120Hz stereo3 Display - 3.7m diagonal 3D high-definition images	Not Applicable.	Public section of the house.	USD 6000	Ht. - 10 cm L - 23 cm W - 30 cm Wt. - 3.13 kg	Ready to use as easily available in market.	Ceilings/walls
	3G Wireless technology	Efficiently works for social interaction and communication.	It's a communicatio technology which ca be used for updatin the data as well a communication.	Hardware's for this technology consists of sensors and actuators.	Needs to be installed in the server room of the Smart home	Depends on level of information needs to be shared and transferred	Hardware compatible in the main server itself.	Available for some features but needs to be configured for certain features.	Can be installed through the server room of the smart home.
	Portable projection Systems	Efficiently works for information & learning. Good in volume, tuning, color, brightness, contrast,sharpness	3 LCD- 9cm Inbuilt Speakers, T Tuner. Functions: I remote with OSI function, 100 chann change, input signal.	Not Applicable.	Anywhere in the house but study and media rooms are prominent.	USD 500 to USD 1000	250(W) * 300(L)*90(H) mm Wt-net : 4.5kgs gross : 6.5kgs	Easily Available in the market and just ready to be purchased	Preferred is ceiling but in certain case walls can also be used.

We are trying to use 3D projection system in order to create a more natural and convenient home environment as if a person will appear to be present in physical and he will be imparting some information, then it will be more easy to grasp it. 3G wireless technologies can be used for data updates of several kinds like health statistics (for automatic keeping update of the heath conditions for other future studies), weather updates, maps, etc. Now out of these technologies 3G wireless technology can be used for both '*one way*' and '*both way*' Communication Technologies. So, based on the details available in the table it can be considered that there should be only one of the 3D projection systems and one of the hardware setup for 3G wireless technologies in the house, while portable projection systems should be multiple depending upon other technologies, which needs to get some information to be displayed. While on the other hand, 3G wireless technologies can be used for '*both way*' communication as well as also for some information and learning. The 3D projection systems should must be installed in some walls or furniture standing next to the wall and also it is preferred that portable projection systems should be installed in the walls but they can also be installed in the ceilings. By integrating these communication technologies in the built environment of home, it can be expected that even advanced and complex technologies can be converted into simple in the terms of using it like for example while talking on the mobile phones other person can be easily observed on the walls, using portable projection systems

and 3G wireless technologies and hence it will make the smart home environment as more and more user-friendly, providing a comfortable living in the built environment of home.

Health Care and Wellness Technology

As we know that in the current society, one of the rising problems is the fact that the life of elderly peoples in the home environment where they need to live alone in many of the cases. By health care and wellness technologies we refer to all those technologies which can be directly installed in the home environment or can be made compatible by some alterations. So, out of all those technologies we have made their classifications in two parts namely Wearable Heath Care and wellness Technologies and Non-Wearable Health Care and Wellness Technologies.

Wearable Heath Care and Wellness Technology

As the name already refers, this classification refers to all those Health Care and Wellness Technologies which can be directly installed on or inside the body of the user. Wearable Heath care systems are basically combination of health Technologies with the informatics in order to easily detect the disorders in advance without facing any serious consequences and well advance in time.

Table 2: Comparative study of available Wearable Health Care and Wellness Technologies

Technical Classification Category	Name	Performance	Short Description	Components (sensors& actuators)	Locations	Cost Effectiveness	Size, Dimension and weight	Readiness	Integrating Components
Wearable Health Care and wellness Technologies	Life Guard	Works efficiently for the monitoring of health status of the astronauts.	Monitors Temp, Respiration, Activity, Heart-rate, ECG, Pulse Oximetry, Blood Pressure.	Sensors are used but not actuators. Accelerometer, Temp, SpO2.	On the human body itself.	Commerciall y not available.	129mm x 100mm x 20mm Wt. – 166 gm	Ready to use but directly to get it from developer lab.	Not applicable.
	HealthGear	Works efficiently for the monitor of the metabolic factors of human being.	Monitors Blood O_2 level & detects sleep apnea events. Bluetooth enabled.	Sensors are used but not actuators.	On the human body itself.	Price not available.	Not Available.	Commercial status not present.	Not applicable.
	E-watch	Works efficiently for day to day life.	Monitors body temp, motion, light, audio, spirometer.	Sensors are used but not actuators.	On the human body itself.	Price not available.	Appears like a wrist watch.	Commercial status not present.	Not applicable.

A study has been made on the available Wearable Heath Care Technologies and has been distinguished on certain parameters which have been shown (see Table 2**).** On the basis of this table it has been realised that Lifeguard (Montgomery et al., 2004) is one of the best Wearable Health Care Technology in the current time while HealthGear (Oliver and Mangas, 2006) and E-watch are good achievements but not at par. But studies have also been made on the possibilities of integrating other features in the Wearable Health Monitoring Systems like multi axis human joint angle measurement, detection of sleep apnea events, blood oxygen level, blood sugar tests, breathing sounds, etc. Simultaneously, studies on corresponding sensors availability is also going on.

Non-Wearable Heath Care and Wellness Technology

As the name already refers, this classification refers to all those Health Technologies which cannot be installed on or inside the user' body but can be installed in the built environment of home without affecting the homely environment of the home. As it is concerned to the

homely environment so of course there are restrictions with the installations of complicated health technologies and hence it is not feasible to have more and more of these types of technologies in the home environment.

Table 3: Details of Non-Wearable Health Care and Wellness Technologies for built home environments

Technical Classification Category	Name	Performance	Short Description	Components (sensors& actuators)	Locations	Cost Effectiveness	Size, Dimension and weight	Readiness	Integrating Components
Non-Wearable Health Care and Wellness technologies	Tread Mill Test Machine	Works efficiently for home environment	Used for the check up of cardiac functions.	Sensors, depends upon model to model.	Family lobby or near fresh air.	Less than USD 3000	1.8 m x 0.85m Ht- upto1.2m Wt. ~ 30 kg	Easily available in the market.	Floors or walls
	EEG Test Machine	Can be used in home environment	Records brains spontaneous electrical activity.	Sensors.	Hardware in server room	Cost not available.	Depends upon models and features.	Available but wireless is under	Walls for attachments which fix with human body

Different Health care Technologies have been considered for getting installed in the built environment of home. And of out of those suitable technologies which seems to be appropriate for home environment have been listed (See Table 3), which are Tread Mile Test set up which is required for heart testing as well as exercise and Electroencephalograph Test set up for brain tests. Although TMT machine can be easily set inside the built environment of home but for EEG, it needs some efforts to make some suitable alterations to get it installed in the built environment of home.

Sustainable Technology

As we know that in the current world we are expecting energy crisis in the coming future, so it becomes quite important for us that as being an architect we should try to reduce the consumption of energy in the built environment of home and should conserve it to avoid or delay the coming energy crisis. So, Sustainable Technologies refers to those technologies which can be installed or considered in the home environment for either reducing the consumption of energy or which can be used for harvesting the renewable sources of energy. For making it more convenient to decide about the Sustainable Technologies, we have divided it into two parts namely Active Sustainable Technologies and Passive Sustainable Technologies.

Active Sustainable Technology

By Active Sustainable Technology, we refers to those Sustainable Technologies which used to first store the energy, through some setup but for storage it needs a conversion of energies from one form to another which decreases the efficiency. Also, it affects the cost of the technologies but it is one of the facts that after energy crisis this can at least develop as an alternative source of energy.

Table 4: Details of Active Sustainable Technologies for built home environments

Technical Classification Category	Name	Performance	Short Description	Components (sensors& actuators)	Locations	Cost Effectiveness	Size, Dimension and weight	Readiness	Integrating Components
Active Sustainable Technologies	Building Integrated Photo Voltaic	Works throughout the year but efficient in summer.	Do no requires extra space for installation and replaces colored glasses.	Light Sensitive dyes.	Can be used on outer surfaces of the house.	Exact cost not available but depends upon quality.	Available in all dimensions. But glass has limits.	Easily available.	Walls on East, west and south but south wall is most appropriate.
	Active Solar Water Pumps	Not that efficient as solar panels itself is less efficient.	Works on a DC motor which is operated using solar panels.	Silicon wafers acts as a sensors in solar panels.	Panels needs to be placed in open areas.	Depends upon the requirement of water.	Depends upon the requirement of water.	Easily available.	Motors at roofs and solar panels on walls as a shading device.

A study of available Active Sustainable Technologies has been made and out of those which have been found suitable for home environments has been listed (see Table 4**).** For home environments, Building Integrated Photo Voltaic (Atheienitis, 2007) can be installed, in the place of glasses as these are basically liquid dyes which need to be just placed between two layers of glasses, with certain precautions and can be used for production of energy. Also, Active Solar Water Pumps can be used in the home environment which consists of a DC motor which is generally operated by using Silicon based Solar Panels.

Passive Sustainable Technology

By Passive Sustainable Technology, we refers to all those Sustainable Technologies which directly uses some concept or renewable source of energy, to reduce the consumption of energy by reducing amount of required energies for any specific job. Also, Passive Sustainable Technologies do not require converting the form of energy from one to another and due to this reason, they have higher efficiency and low cost investments. Based on the studies made on the several Passive Sustainable Technologies (see Table 5), few of the suitable and feasible Passive Sustainable Technologies for built home environments have been listed.

Table 5: Details of Passive Sustainable Technologies for built home environments

Technical Classification Category	Name	Performance	Short Description	Components (sensors& actuators)	Locations	Cost Effectiveness	Size, Dimension and weight	Readiness	Integrating Components
Passive Sustainable Technologies	Passive Solar Water Purifier	Works throughout the year but efficient in summers.	Applied principle water evaporates at several temp.	Not Applicable.	Above the house.	Price not available.	1.4m x 0.8m Ht. – 0.6m	Commercially not available. But easy to made in lab.	Ceiling
	Passive Solar Design Concept	Works efficiently throughout the year	It reduces energy wastage & enhance comfort ability.	Not Applicable.	Overall in the house. But East, South & West are significant walls.	Depends upon Geographical factors.	Depends upon Geographical factors.	Concepts ready needs to implicated as per given conditions.	Ceiling and walls
	Passive solar water lifter	Works throughout the year but efficient in summer.	Works on Bernoulli's Theory.	Not Applicable.	Above the house.	Comparative price is quite cheap.	Requirement dependent.	Can be easily made for given requirements.	Roofs
	Passive Solar Air Conditioner	Works throughout the year	More efficient for large spaces.	Not Applicable.	1 unit outside the house and other inside.	Depends upon need.	Depends upon area of application.	Available in the market but not easily.	Walls and Roofs.

Based on Table 2, it can be notified that if we can use Passive Solar Water Purifiers, Passive Solar Design Concepts (Brian et al., 2008), Passive Solar Water-lifters and Passive Solar Air Conditioners, then it can really reduce the amount of energy expenditure in the home

environments and can prove to be a money saving source as well as a source for delaying the expected energy crisis.

Home's Health Monitoring Systems

It's a fact that if a house with such advanced technologies are going to be made, then although we will try to make it simple in appearance but even though fact will remain the truth that there will be lots of complex systems and sub-systems installed inside the home and which is not possible for the users of the house to identify the problems, if arises. Moreover, to make the built environment of home more intelligent and perfect we need some technologies to identify the problems for the other technologies or features and also for over viewing and maintaining the other installed technologies, in order to reduce the maintenance cost as well as complications. Then proper actions can be taken in real time domain, by using some mechatronic systems.

Structural Health Monitoring Technology

By Structural Health Monitoring Technology, we refer to all those technologies which are/ can be used for monitoring the condition or health of the structural members of the house. By using these technologies, we want to make sure that the chances of severe damage to the home should be either removed or minimized and to make the occupants of the house more and more safe and this facility will give the sufficient time well in advance so that proper retrofitting or risk management can be done. Study of different Structural Health Monitoring Technology has been made and then compares so that a suitable structural health monitoring technology can be considered for the built environment of home (see Table 6).

Table 6: Comparative study of available Structural Health Monitoring Technology

Technical Classification Category	Name	Performance	Short Description	Components (sensors& actuators)	Locations	Cost Effectiveness	Size, Dimension and weight	Readiness	Integrating Components
Structural Health Monitoring Technologies	Electro Mechanical Impedance (EMI) Technique.	Works efficiently but effects the cost & complexity.	Identifies damage, its location & damage intensity	Sensors and actuators both as Piezoelectric Transducers.	Embedded in concrete/ fixed on steel structures by adhesives.	Up to USD 140 per sensor.	Size varies as per need, but 20mm x 20mm, easily available	Sensors available but need to be fixed by experts.	Columns, beams and roofs.
	Global Vibration Techniques Using Strain Gauges.	Works efficiently and comparatively cheaper.	Can identify the damage but can't locate it.	Only sensors No actuators.	Embedded in concrete/ fixed on steel structure by adhesive	USD 50 to 100 per sensor	Size varies as per need.	Sensors available but need to be fixed by experts.	Columns, beams and roofs.
	Global Positioning Systems.	Works with lesser accuracy	Uses a GPS device for real time SHM	No additional sensors/actuator s are requires.	Just needs to get in the network area	Choice of user. USD 100 to 300.	Depends on receiver unit of GPS.	No readily available.	Not Applicable

Based on Table 6, it can be easily observed that here we have discussed about three of the Structural Health Monitoring Technologies which can be used in the built environment of home namely EMI Technique (Bhalla et al., 2009) with Piezoelectric sensors, Global Vibration techniques with Strain Gauge sensors and GPS Technology. Now based on the comparative study of these technologies from Table 6, it can be clarified that, Electro Mechanical Impedance technique is most efficient and suitable for Structural Health Monitoring of home environment as it can be used for the evaluations of most of the parameters like damage identification, damage location and damage intensity with higher accuracy, while other technologies are not capable of doing the same.

Energy and Resource Monitoring Technology

Basically energy monitoring is a management technique that uses energy information as some feedback to reduce or eliminate the energy wastage and control the currently existing level of energy use and also to improve the operating procedure. So, by Energy Monitoring Technology we refer to all those technologies which can be used in the above stated purpose. It can be said that Energy Monitoring Technologies are the combination of a set of steps which can be stated as recording, analysing, comparing, monitoring, reporting and then controlling.

Table 7: Details of Energy & Resource Monitoring Technologies for built home environments

Technical Classification Category	Name	Performance	Short Description	Components (sensors& actuators)	Locations	Cost Effectiveness	Size, Dimension and weight	Readiness	Integrating Components
Energy and Resource Monitoring Technology	Automatic Lighting Controls.	Efficient for reducing the wastage of light.	Applicable for minimum load of 125Watt.	Sensors – Passive IR, Ultrasonic occupancy, Dual tech, Vacancy, Daylight override.	Every room needs sp. Sensors.	USD 25 to 50.	Depends upon Location.	Easily available.	Roofs or Walls.
	Home Automation & Control	Efficient for use in home environment.	Controls light, heating/cooling, video capture.	Not Applicable.	Server room	Up to USD 150.	Not applicable.	Easily available.	Not Applicable
	Automatic Taps.	Efficient for home environment.	Fewer complex for operating.	Sensors – Infrared rays.	Kitchens & Bathrooms.	USD 100	Depends upon model. Wt. - 0.5 kg	Easily available.	Walls.

Based on studies made on several Energy & Resource Monitoring Technologies (see Table 7), it has been found that few of the suitable technologies for the built environment of home are Automatic Lighting Controls, Home Automation and Control through internet and Automatic taps. On the basis of Table 7, it can be noticed that Automatic Lighting Controls and Automatic Taps are quite essential for Smart Home environment but we also need Home Automation and Controls simultaneously as Automatic Lighting Controls do not gives the remote access facility and also by using Home Automation we can controls several other parameters like heating, cooling, video access, etc.

OVERALL VIEW OF MECHATRONIC SYSTEMS

By Mechatronic Systems we refer to those systems which can receive the signals through the sensors or the actuators. Those systems can analyze in order to perform the desired mechanical actions. Therefore, it is not always necessary that sensors and actuators are thoroughly fitted inside the mechanical units. This mechanical unit is a kind of subsystem and can receive the signals through the sensors fitted into other subsystems. This can be managed through the appropriate informatics action (See Figure 3). On the basis of the desired mechanical action we can divide the mechatronic systems into four subsystems, namely Service Robots, Maintenance Robots, Humanoids and Exoskeleton.

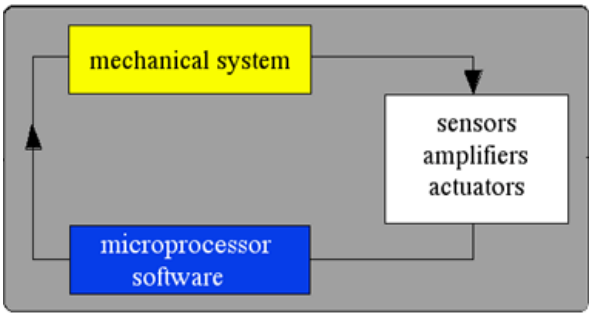

Figure 3: Basic concept of Mechatronic Systems

Service Robots

By service robots we refer to those mechatronic systems, which can be used for performing the particular set of home services like care services. These services can be performed by Robotic Systems in order to make disabled or older people`s lives easier. These service robots can be guided through the overall home informatics network which communicating with the all relevant subsystems (See Figure 4). (Lst. BRI, Prof. Bock, 2009)

Figure 4: Service Robot, Lst: BRI, TUM

Figure 5: Maintenance Robot, Lst: BRI, TUM

Maintenance Robot

By maintenance robots we refer to those mechatronic systems which can save the time of the human beings by performing the boring jobs. Using the smart home environments, problems can be identified within the building's network and then can be solved automatically and can also reduce the cost for repair of disabled elements. It also the focus on social life of human beings as it solves the technical problems without human interactions using artificial intelligence (See Figure 5). (Lst. BRI, Prof. Bock, 2009)

Humanoids

By introducing the sensors networks inside the built environment of homes, the orientation and trajectory development or planning is being made easily. As a result, the navigation of complex and intelligent humanoid robots can be performed relatively much easier than without the sensors infrastructure. These humanoid robots could be used to assist humans in complex and various actions and even form a kind of complementary substitute for social interaction (See Figure 6). (Lst. BRI, Prof. Bock, 2009)

Figure 6: Humanoids, Lst: BRI, TUM

Figure 7: Exoskeleton, Lst: BRI, TUM

Exoskeleton

By exoskeleton, we refer to those mechatronic systems which can be used for providing physical power and safety to the human beings, for hard, difficult and dangerous assignments. It can also be used for disabled people to give them a higher level of independency and can also be used for fast recovering after accidents or diseases (See Figure 7). (Lst. BRI, Prof. Bock, 2009)

5. CONCLUSION

In the current time we talk of energy crisis, smart environment, sustainable technologies for the coming future, but based on the studies made in the area of these all technologies it can be figured out that the futuristic houses are going to itself behave like a complex system which will be integrating several subsystems itself. Although, this home will be a complex system in itself but by the assistance of these subsystems, it can surely take the life of the human beings towards the next level of comfort. It can be expected that in the futuristic homes, comparatively a much higher level of independence can be achieved.

REFERENCES

[1] K. Montgomery, C. Mundt, G. Thonier, A. Tellier, U. Udoh, V. Barker, R. Ricks, L. Giovangrandi, P. Davies, Y. Cagle, J. Swain, J. Hines, G. Kovacs, “Lifeguard- A Personal Physiological Monitor For Extreme Environments” 2004

[2] S. Bhalla, A. Gupta, S. Bansal, T. Garg, “Ultra low cost adaptations of Electro-Mechanical Impedance (EMI) Technique for Structural Health Monitoring” 2009

[3] A. Atheienitis, “Design of solar home with BIPV-Thermal system and ground source heat pump” 2007

[4] N. Oliver & F. Mangas, “HealthGear: A Real-time Wearable System for Monitoring and Analyzing Physiological Signals” 2006.

[5] W. Brien, T. Kesik, A. Atheienitis, “The use of solar design days in a passive solar house conceptual design tool” 2008