



Advanced

SENsOr

development
for

ATtention,

stress,

vigilance &

sleep/
wakefulness

monitoring

INSIDE THIS
ISSUE:

Editorial	1
In this issue	1
1st Pan European SENSATION workshop	2
Sleep as a marker for chronic stress	3
Automatic sleep staging	4
A Finger Ring sensor for SpO ₂ Measurement	4
Silver decorated arrays of Carbon Nanotubes	6
MATSENSE sen- sor prototype	7
SENSATION Communication Platform	8
Data Privacy and Security in SEN- SATION	9
Electronic tool for pilot Applications	10
Join SENSATION User Forum	11

SENSATION 1st year results

Welcome to SENSATION's 2nd Newsletter. SENSATION is an EC FP6 Integrated Project that aims to explore a wide range of micro and nano sensor technologies, targeting at unobtrusive, cost-effective, real-time monitoring, detection and prediction of human physiological state in relation to wakefulness, fatigue and stress, anytime, everywhere and for everybody.

SENSATION is already one year old and a lot of research activities have taken place since its launching on January

2004. Firm theoretical background for the definition of physiological states and the development of the sensors has been set during this year and the initial results are already put into practice for further development activities of the second project year.

Since the focus of SENSATION consortium is research and development, your opinion would be of high interest to us. We therefore proudly invite all of you to join us and meet us in the first Pan European SENSATION workshop

that will be held in Warsaw, Poland on the 11th of March 2005 (more at page 2).

In this issue selected topics of SENSATION first-year research are presented for your information.

SENSATION consortium will continue to keep you updated on its activities and results. Our next Newsletter is scheduled for June 2005, with fresh stories from SENSATION workshop and high-end technology results. Until then have a SENSATIONAL year.

In this Issue:

Selected issues are presented to this newsletter describing certain aspects of the project's activities. Of course a lot more are happening that could be found at our website: www.sensation-eu.org.

Initially the First Pan European workshop is introduced and the preliminary agenda is provided. (page2).

At page 4 the background of the development of stress detection systems based on sleep monitoring is briefly presented. The soft-

ware for the automatic sleep staging developed by GBAF is illustrated in page 4.

Following, three early-prototype sensors are briefly described. The Finger Ring sensor for SpO₂ Measurement at page 4, the electrode based on Carbon Nanotubes at page 6 and the MATSENSE sensor prototype at page 7.

Also the SENSATION communication platform is described at page 8 and the Data Privacy and Security considered within SEN-

SATION project is documented at page 9.

Finally an assistive electronic tool for on-line data input during validation phases is displayed at page 10.

Did you find our Newsletter interesting? Forward it to your colleagues and give them the opportunity to subscribe and receive the forthcoming issues. More information on how to join can be found at page 11.

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FOR MORE INFO: www.sensation-eu.org

1st Pan European SENSATION Workshop

Registration soon available at:

www.sensation-eu.org

March 11th, Warsaw Poland

Things are progressing fast within SENSATION project and the Consortium is focused on the organisation of the 1st Pan-European workshop where project activities and initial results are going to be presented.

SENSATION's workshop is going to be held on March 11th, at Warsaw, Poland. Group of Biosignal Analysis Fundamentals (GBAF), Polish Academy of Sciences is the SENSATION partner that will kindly host the event at its

premises.

The objective of this workshop is to widely disseminate the SENSATION concept, diffuse preliminary results and get feedback from the experts' community before actual realisation of the sensors and the applications. The workshop's main theme will focus on the project concept and the project technical developments in relation to micro/nano sensors development.

A parallel, sensor exhibition is also programmed to take place during this event, in order to stimulate experts' participation. In addition, the Workshop is supported by three external speakers, each having an expertise in the three major research fields of the project; sleep relation to health, nanotechnology and the future, involuntary sleep impact to safety and security.

Preliminary Workshop Agenda

Friday, 11 March 2005

8:30-9:00 Registration

9:00-9:30 Welcome Speeches

Wlodzimierz Klonowski (GBAF)

Thomas Sommer (EC)

9:30-9:45 The problem of sleep and the SENSATION approach

Evangelos Bekiaris (CERTH/HIT)

9:45-10:00 Sleep stages and classification

Alex Bullinger (COAT)

10:00-10:15 Sleep & Stress

Goran Kecklund (Karolinska Institute)

10:15-10:30 Voluntary and involuntary transitions from wake to sleep: Do they differ?

Alain Muzet (CNRS/CEPA)

10:30-11:00 Sleep & Health

Alexandros Vgontzas

11:00-11:10 Short presentation of Sensors Exhibition

Evangelos Bekiaris

Coffee Break

11:30-12:30 New concepts for wireless sleep recording

Anand Kumar (MEDCARE)

12:30-13:00 Sleep & Safety

Pierre Philip (Pellegrin University Hospital)

Lunch Break

14:30-14:45 The importance of Normative Sleep Data

Georg Dorffner/ Peter Anderer (OFAI)

14:45-15:00 Sensational Sensor concepts for attention, stress, vigilance and sleep in the go

15:00-15:30 Sleep & Nanotechnology

Johan Suls (IMEC)

15:30-15:45 New Approaches to Nonlinear EEG Analysis for Wake-Sleep monitoring

Evangelos Bekiaris

15:45-16:45 Prioritisation of sensors for medical and industrial applications

Stella Nikolaou (HIT), Stavroula Maglaveras (POULIADIS)

16:45-17:00 Conclusions

Evangelos Bekiaris

Sleep as a marker for chronic stress – implications for stress detection

One of SENSATION's first deliverables was the "Report on methods and classification of stress, inattention and emotional states".

Stress is a physiological state that affects us everyday. From a biological point of view stress means activation or arousal, which aims at promoting a redirection of energy to body sites where they are needed most. However, stress also involves psychological elements and the physiological stress response is to a large extent dependent on the individual's appraisal (evaluation) of the stress situation. Thus, stress occurs if one expects that a situation is harmful, threatening or challenging.

The negative consequences of stress, for example cardiovascular disease, peptic ulcer and musculoskeletal disorders, are, however, not related to acute stress. On the contrary, the acute stress response is related to increased alertness and improved performance, and is no problem as long as the stress activation can be shut off when stress terminates. Instead it is prolonged or chronic stress that is causing illness and functional impairment.

Chronic stress often results in ele-

vated activation throughout the 24-hour period. The reason for this seems to be difficulties to shut off the stress activation systems. As a consequence, disturbed sleep is often observed in individual's suffering from chronic stress. The elevated arousal at bedtime and during nighttime interferes with sleep and causes insomnia and sleep fragmentation. In the long run, disturbed sleep impairs biological restitution, which may play an important role for stress-related disease development.

This has many practical implications for development of a stress detection system. Firstly, such a system should include some (unobtrusive) recording of sleep, since disturbed sleep is one of the best markers of chronic stress. Secondly, a stress detection system should also record other stress markers, such as heart rate and blood pressure, during sleep and rest. Sleep offers good possibility to obtain good recordings since the influence of physical activity and posture is under control. Moreover, increased physiological activation together with disturbed sleep suggests a strong link with chronic stress. In particular during treatment of chronic stress, it can be very valu-

able to obtain information of whether sleep quality has improved and physiological activation been reduced. Such information can increase the motivation for the patient to continue with the treatment program. Thirdly, physiological recordings during work or free time may also be of interest, however, only if physical activity can be under control. Increased activation may also be rather non-specific and elevated levels can occur during pleasant activities as well. Finally, it should be pointed out that today there are no recording systems related to detection of chronic stress. There are of course other recording systems that measure several physiological parameters simultaneously, but these are not feasible for home recordings or are too obtrusive. On the other hand, more unobtrusive recording systems, such as wrist actigraphy, often lack the possibility to record stress markers such as heart rate or blood pressure.

"Today there are no recording systems related to detection of chronic stress"

Automatic sleep staging

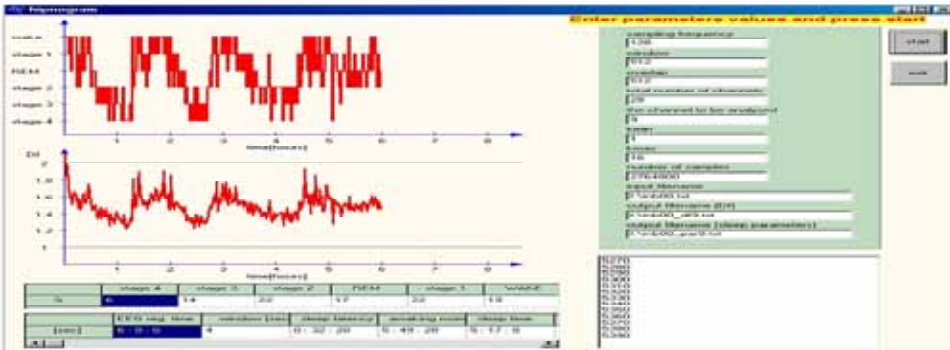
In the Group of Biosignal Analysis Fundamentals (GBAF), Polish Academy of Sciences, Warsaw, we develop new methods of biosignal processing and analysis, based on nonlinear and symbolic dynamics, for sleep staging, alertness monitoring, assessment of depth of anaesthesia, neuro-feedback. The most

promising are methods based on Higu-chi's fractal dimension of EEG [1,2] and of HRV [3]. GBAF made *FRAST™* program for automatic sleep staging that is based on analysis of fractal dimension of one-channel EEG. On a PC with 1.8 GHz processor it takes only about 2 min. to construct the hypnogram of the whole-

night (ca. 6 h.) sleep. The program may easily be adapted to analyse different EEG channels, depending on doctors' demands. Version 2.x will make possible analysis of short epochs for wakefulness-sleep monitoring.

References:

- [1] Fractal dimension method for analysis of signals from sensors, *SENSATION Internal Report, SENS_GBAF_SP1_WP1_1_v1_FractalMethod.doc*, October 2004.
- [2] W. Klonowski, E. Olejarczyk, and R. Stepień, Complexity of Polysomnogram Signals, *WSEAS Transactions on Computers*, vol 3, no. 5, pp. 1290-1294, 2004.
- [3] W.Klonowski, E. Olejarczyk, R. Stepień, G.Varoneckas, A.Alonderis, D.Zemaityte, Fractal and Symbolic Analysis of Heart Rate Variability During Sleep in Healthy Subjects, submitted to *IEEE Trans. Biomedical Engineering*.



An example of automatic hypnogram obtained using *FRAST™* program (version 1.2)

A Finger Ring sensor for SpO₂ Measurement

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An embedded miniaturized sensor for monitoring pulse and arterial blood oxygen saturation (SpO₂) in a finger ring device is being developed. With respect to existing products, the location of the sensor is original and allows a better comfort for long time monitoring. Moreover, the concept is expected to efficiently cancel the motion artefacts thanks to a novel measurement technique and thanks to an improved electronics and signal processing.

In the framework of the European integrated project SENSATION (Advanced sensor develop-

ment for attention, stress, vigilance and sleep/wakefulness monitoring), CSEM and EIVD are developing a new wearable sensor for monitoring heart rate (HR) and arterial blood oxygen saturation (SpO₂) in a finger ring device.

The SpO₂ is a key physiological parameter, especially useful for patients during surgery or intensive care when normal breathing is disturbed. It is also important for people suffering of sleep apnea. A good monitoring of SpO₂ during everyday life and sleep could be a significant step towards an improvement of their sleep and life quality.

Existing commercial products usually measure the SpO₂ at the fingertip, the earlobe or the forehead. These locations provide good signals but are neither very comfortable nor discreet. On the other hand, for most people, a ring is a jewel that is comfortable to wear for very long periods, if not forever. Therefore, a ring sensor would be both comfortable and discreet (who would guess that a physiological sensor is concealed in a jewel?). The difficulty comes from a lower modulated signal and higher signal artefacts.

The classical SpO₂ measurement technique [1, 2] is elegant, because the pulsing change of colour due to the periodic flux of arterial blood can be extracted from the background colour of the other body fluids, flesh, skin, bones, tendons, etc. This extraction gives the arterial-blood colour—usually characterized by the ratio of values measured at 660 nm and 940 nm. From the colour of the arterial blood, it is easy to deduce the oxygen concentration (remember that oxygenated arterial blood is roughly speaking ‘red’ while venous blood is roughly speaking ‘blue’). However, the measurement can be totally wrong if the pulsing change of colour has other causes than the periodic flux of arterial blood. For example, any motion of the sensor, any finger flexion/extension (for fingertip sensors), or any change of ambient light induces significant artefacts.

In the project, EIVD had developed an electronic module allowing a very good rejection of ambient light artefacts using an original modulation technique. The motion artefacts are expected to be significantly lower thanks to CSEM’s novel optical setup



Figure 1: The finger ring first study prototype.

that allows taking the colour of deep tissues, and therefore removing the effect of skin pigments. Signal processing algorithms are also foreseen to play an important role in the artefact management.

Figure 1 shows the first study prototype. Part of the electronics is in the ring itself, but most of it is so far in a module at the wrist (see Figure 2). At this stage, since the focus is in fact to develop a demonstrator, no attempt to miniaturize the processing module has been made. In the future, one can imagine having all electronics in the ring, including a wireless transmission.



Figure 2: The wrist case housing the processing module.

Two possibilities exist to power up the processing module: either from a 3.6V battery or from the USB port. In parallel, application software running on PC was developed to communicate with the processing module via the USB port in order to conveniently download the processing algorithms into the onboard DSP and upload the measured data in real time.

Figure 3 shows a typical waveform acquired by the system. At the time of writing this report (Dec. 2004) the hardware design is being tested and validated using the first prototype. The tuning of the signal proc-

essing algorithms and the calibration is currently going on. Based on the experience that will be gained in the coming months, a feasibility report will be written and is expected to be delivered to the Project Coordinator by June 2005.

If the feasibility assessment is positive and if the finger-ring sensor is selected as a good potential candidate in the context of attention, stress, vigilance. Sleep/wakefulness monitoring, then more sensors will be built and put at the disposal of other project partners.

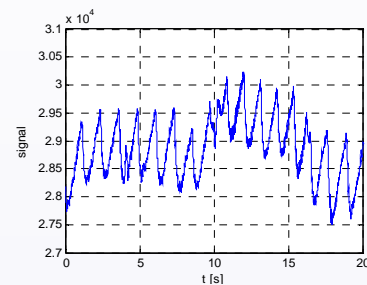


Figure 3: Typical signal from one of the photodiode after background subtraction. The closely spaced pulses correspond to the heart beats. External perturbations were applied to test immunity to sudden ambient light changes: (a) Flash light at $t = 4$ s, (b) 1 kW spotlight turned on at $t = 10$ s. Since the SpO₂ measurement will ultimately be computed from the peak-to-peak amplitudes of the photodiode signals, this preliminary result is thus very encouraging.

References

- [1] J. Moyle (2002) *Pulse oximetry* ISBN 0 7279 1740 4
- [2] .G. Webster (1997) *Design of pulse oximeters* ISBN 0 7503 0467 7

Silver decorated arrays of Carbon Nanotubes

Nano-electronics Centre, University of Surrey

The EEG electrode based on Carbon Nanotubes (CNT) that will be developed within SENSATION is based on the transduction of the biopotentials to an electronic signal. The sensor must be able to detect the electrical activity of the human body, which is

unique, a target is vaporised using a high energy laser pulse. A target made of melted silver chloride was ablated with a laser (6 J/cm²) operating at a wavelength of 248 nm. The ablated AgCl vaporized and decomposed into metallic silver and gaseous chlorine and the vapours of metal were

the CNT. Figure 2 shows a Transmission Electron Microscopy (TEM) image with a region subject to high magnification of the wall of a CNT. The metallic particles have well pronounced crystal structure with the lattice distance typical for Face Centered Cell (FCC) of silver. The size of the particles appears to be dependent of the number of laser shots. This effect is currently under investigation. The fact that the particles deposited are Ag and not AgCl does not suppose a problem because these Ag particles can be easily chlorinated with a simple electrochemical reaction.

In conclusion, CNT arrays with

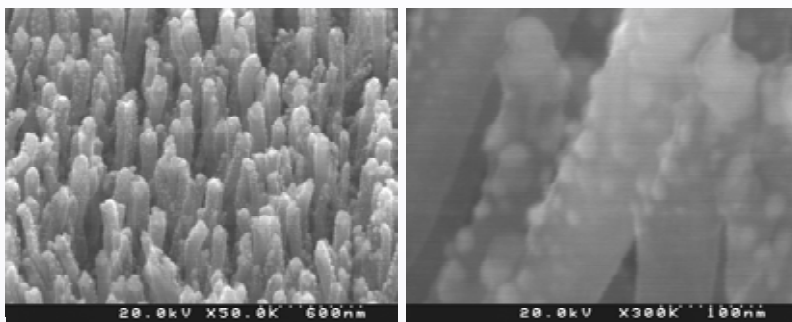


Figure 1: (a) SEM image showing an array of CNTs coated with Ag. (b) Magnification of (a) showing the small Ag droplets covering the walls of the tubes.

based in the flow of ions to an electron flow and provide an appropriate response. For this reason, the CNT array must be coated with an ion exchange layer. Traditionally, AgCl coated electrodes are used for this transduction. Apart from being able to act as transducing layer this material is not very soluble and therefore does not dissolve when in contact with an aqueous media.

During the first period of the Enobio development we have focussed on the coating of the CNT with AgCl. The coating technique that has been chosen for the first investigation is laser ablation. In this tech-

deposited on the outside wall of the carbon nanotubes used as a template. Different numbers of laser shots were used to see how it influences the deposited size of silver crystals as well as the coverage of the nanotube surface. Figure 1 (a) shows a Scanning Electron Microscope (SEM) image of a CNT array which has been covered with Ag. Figure 1(b) presents a magnification of the tubes that shows the Ag particles coating the walls extremely uniformly on the CNTs.

Figure 1(b) clearly shows the small droplets covering the walls of the CNTs. Currently, the number of laser shots is being increased to achieve a homogeneous coverage of all the surface of

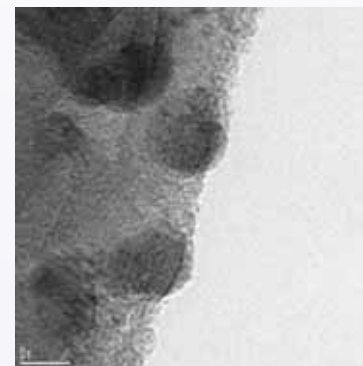


Figure 2: TEM image of a Ag decorated CNT wall.

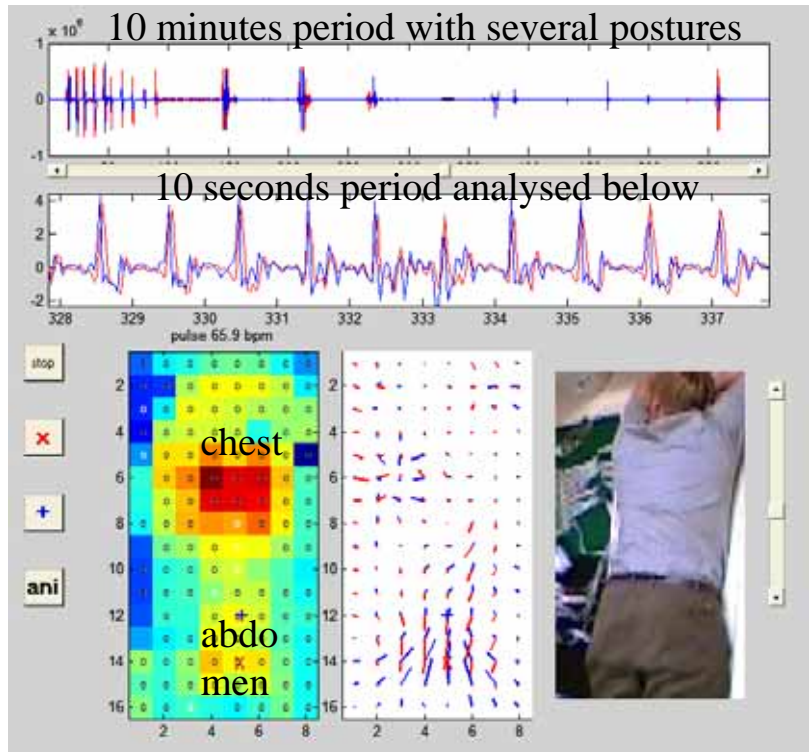
homogeneously decorated of Ag particles have been produced. The CNT have now a coating with an ionic exchange transduction layer that will be used to transduce ionic flows in the human body.

MATSENSE sensor prototype

J.M.Kortelainen, VTT - Technical Research Center of Finland

Technical Research Center of Finland is the developer for EMFiTT foil sensor applications in Sensation IP. The measuring principle is based on the electret property, relating to static electric dipoles generated into the voids of thin polypropylene film. The electret film generates charge corresponding with the pressing force. Sensor manufacturer Emfit corp. has developed their product further for the SENSATION prototype called MATSENSE, which includes multiple elements to measure pressure profile of a lying person on the bed mattress. Closely similar sensor matrix will be used for seats with another sensor prototype called SEFO.

The measurement electronics is developed by VTT during the Sensation project, to achieve good measuring sensitivity for multiple elements. The principle used for amplifying stage is a novel idea, being specifically suitable for the charge self-generating electret film. The amplifier uses analog switches for both multiplexing measurement channels and for switching the integrating amplifier feedback loop. With the selected ultra-low leakage switches and 20 bit A/D converter, the high dynamic range of sensor can be utilized. The compact electronics design for the integrating stage does the anti-alias filtering at the same.



The data is collected to PC via USB2.0 module. The highest data rate would be 512 kbits/second, targeted for 512 measuring points and 50 Hz sampling rate.

The figure above shows two 64 channel PCB cards for the prototype electronics, and two 64 channel Matsense foils with dimensions of 40x40 cm².

The figure shows firstly the measurement trends for two channels. The uppermost trend shows the 10 minutes period with changing the body posture. The second trend is a 10 seconds zoomed time period when person I lying on prostrate, showing

clearly the heart beat.

The coloured graph shows the pressure profile on the 80x40 cm² sensor area, for the selected 10 seconds time period. The middle graph shows the acoustic transfer of pressure variation, giving e.g. location of the heart and stomach. The rightmost image shows the camera image used as reference during the development work.

SENSATION Communication Platform

SENSATION project has as main objective the research and development of new families of sensors as well as the implementation of innovative algorithms for sleep management and wakefulness' states awareness. Both, sensors and algorithms will be the base for the development of applications in medical and industrial fields. Communications play a crucial role in the project, since they provide part of the means for the correct integration of the whole system.

Different aspects arise when having to communicate several sensors together with potential local or remote applications: how do sensors communicate with the device that receives the data? If this device is part of a remote application, how does this device communicate with such application? In order to deal with these issues, the communications platform has been divided into three levels: The Body Area Network (BAN), the Local Area Network

(LAN) and the Wide Area Network (WAN).

The BAN aims at communicating the sensors with a portable central device called Personal Data Processing Unit (PDPU); this device is capable of performing data analysis, allows user interaction and manages the communication of sensors with eventual external modules of the application in which it is being used. Allowing wireless communications in the sensors is one of the main challenges of the whole project, and the key to succeed in the implementation of a comfortable and unobtrusive system.

The LAN provides connectivity in a local environment. Its objective is to communicate different Personal Data Processing Units together with other devices (PC's, PDPA's, etc.) in order to make a collaborative network available where local applications can take advantage of the interaction among them.

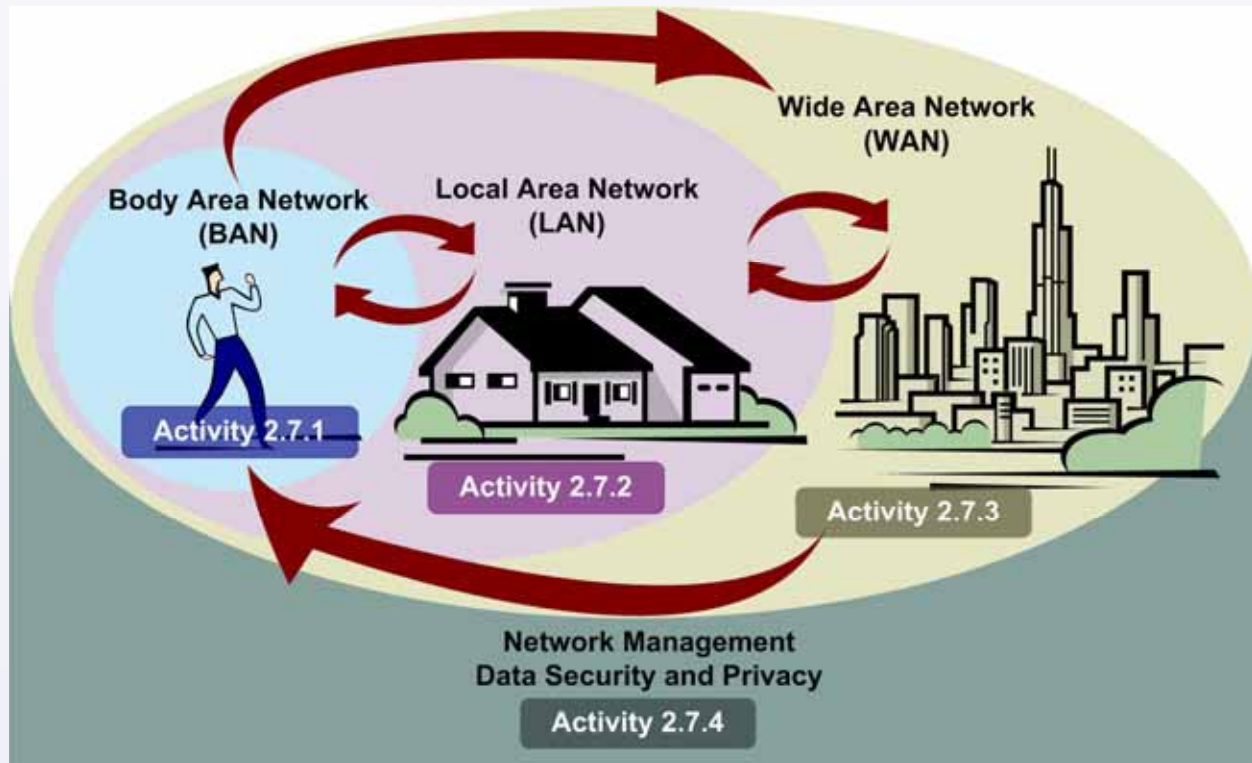
The main purpose of the WAN is to communicate data for applications

that exceed the "local" boundaries in a distributed system. The WAN represents an important and innovative added value to the current state of the art on sleepiness and fatigue monitoring systems. It gives the possibility of remoteness, with the consequent benefits that this may bring.

In order to illustrate the aforementioned concepts, an example of a specific scenario follows, represented in next figure.

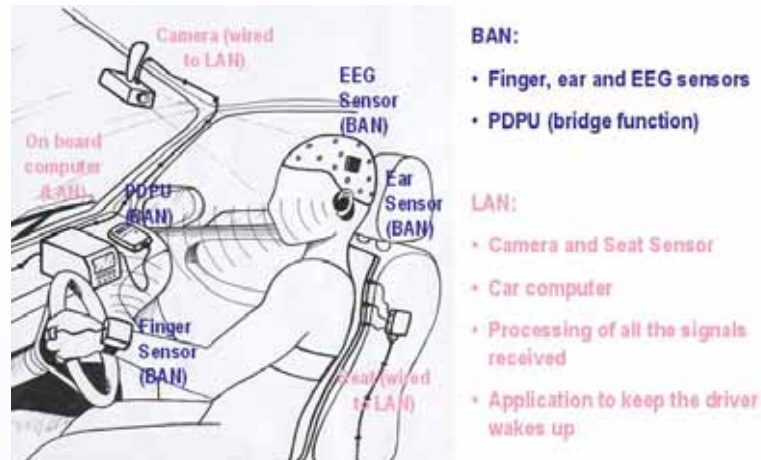
A car driver wears a BAN formed by an EEG sensor, an Ear sensor and a Finger sensor, and a central device (PDPU) that receives the information from the sensors through wireless links. In this case, the PDPU doesn't have to perform any computation and just resends the data acquired by the sensors to the LAN.

The LAN is composed of an on-board computer (integrated in the car) that receives information from the BAN, and of a camera and a seat sensor directly connected to it. All the data are processed by a LAN



application, with the final objective of detecting driver's sleepiness and keeping him awake.

An extension of this scenario could be a fleet of cars equipped with the above-described system, with the additional capacity of automatically sending the information generated by the application in the LAN to a central service in the WAN in order to keep the different drivers monitored.



Data Privacy and Security in SENSATION

Due to SENSATION is also focused in medical environments, the EU Recommendation on the Protection of Medical Data has been considered in order to prepare the security and privacy guidelines affecting SENSATION Applications and Communications.

The main EU Directives affecting the SENSATION project in terms of security and privacy are: the EU Data Protection Directive (95/46/EC) and the Electronic Communications Data Protection Directive (2002/58/EC). The first Directive objective is to allow the free flow of personal data between Member States by harmonising the level of adequate protection granted to individuals. It sets forth the applicable law, conditions for data processing, information to be given to the data subject, the latter's right of access, object, confidentiality and security of processing, obligation of notification and content of such noti-

fication, as well as the limitations to the transfer of data to third countries imposed within the harmonised scope. The second Directive is designed to "particularise and complement" the Data Protection Directive (95/46/EC). It aims to ensure that all EU Member States apply equivalent levels of privacy protection regarding the processing of personal data in the electronic communications sector while ensuring that the free movement of data or equipment, or the provision of services in the EU is not obstructed.

The main conclusions extracted from the analysis of the EU Privacy Directives, EU Recommendations and some national laws are that medical data are considered, in the EU Directive and in the national laws, as data that requires a high level of security in order to guarantee the patients care and their case history privacy. So, all electronic systems that

process medical data shall incorporate strong security mechanism at communications and application level to guarantee the Medical and Personal data privacy. Data encryption is mandatory at all levels (databases, temporary files, communications, etc.) and it is also recommended to use anonymous data (with no possibility to identify people). Authentication mechanism shall be also included in the Communications and Applications, to identify correctly authorized users (sensors and applications in case of communications). Profiles are also required in order to implement users selective access to data. Any access to sensitive personal data shall be audited to check and establish, a posteriori, who has accessed to data and whom and what personal data have been processed and when.

Electronic tool for pilot Applications

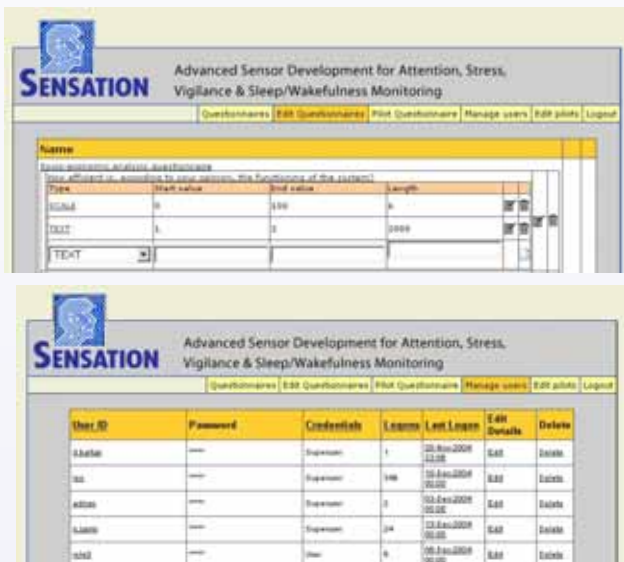
SENSATION will also develop a number of assistive tools for helping at specific tasks. Here the electronic tool for questionnaire analysis is presented.

The technical achievements of the SENSATION project will be demonstrated and evaluated through the implementation of a number of Pilot Applications. Each one of these Pilots (more than 30 in total) will test

different project objectives involving the use of different sensors or methodologies advanced within the framework of SENSATION. The success or failure of these pilots is going to determine the success or failure of the whole project and should therefore be measurable. For this reason, various types of assessments have been defined to evaluate the success or failure of subsystems demonstrated through Pilots. These

assessments are carried out mainly through the analysis of information gathered from questionnaires, filled in by users of the Pilots. To assist this data collection, analysis and reporting processes, some electronic tools had to be developed.

“SENSATION will implement on-line collection of data for all pilots through the use of electronic questionnaires”



Figures: Electronic tool for on-line questionnaires

Methods have been provided to register the users that fill in the questionnaires and gather the data in underlying databases. A common repository is provided to evaluate and analyse available data for each pilot separately but also consolidating data from various pilots, to derive general results.

This capability for statistical analysis and reporting of results has been integrated by accumulation of all user entries in Excel sheets downloadable remotely by authorised users. The system also allows remote users with administrator privileges to design and activate new questionnaires as well as

to manage all users along with their access rights. The capabilities of these tools will be refined in the course of the project according to the needs of planned and emerging Pilot Applications.

Join SENSATION User Forum



SENSATION Consortium counts highly your opinion and supports your involvement in its developments. A group of experts world-wide are members of the SENSATION's User Forum Group. User Forum members are privileged experts and receive project news, invitations for project's events, workshops, etc., where they are invited to participate in brainstorming sessions and questionnaire surveys and provide their views according to their areas of expertise.

Members of the User Forum will have access to certain SENSATION deliverables and comments received for all of the projects' research activities and products will be highly welcomed.

If you want to be a member of the SENSATION User Forum and be an active member of one of the most important initiatives of the specific research areas, we invite you to fill-in the following

application form and send it to: Dr Angelos Amditis (angelos@esd.ece.ntua.gr) or fax to: 00302107722291.

User Forum Group Application Form

Yes, I want to participate to SENSATION User Forum Group

I understand that I will have no obligations whatsoever and every possible participation to the project's activities will be strictly voluntarily. I can also withdraw my participation at any time with a simple E-mail to: angelos@esd.ece.ntua.gr

First Name:	
Last Name:	
	Mr <input type="checkbox"/> Ms <input type="checkbox"/>
Company:	
Function in Company:	
Interest in SENSATION:	
E-mail	
Telephone:	
Address:	
Interest in joining Special Focus Groups? (If yes, in which? Please specify)	

Special Focus Groups

Within SENSATION Special Focus Groups will be also formed. Participants of the Focus Groups will be able to interact and exchange opinions on specific subjects through the SENSATION website and during SENSATION brainstorming sessions.

The SENSATION Special Focus Groups formed up to now are:

- Sleep, stress and work organization
- Vigilance on the move
- Healthy sleep
- Hospital applications
- Sensors miniaturization
- Data fusion and algorithms

More information on how to join Special Focus Groups will be communicated at the next Newsletter and published in the SENSATION web site (www.sensation-eu.org).