

## Innovative aspects of CHIRON

### A. INNOVATION IN THE OVERALL CHIRON APPROACH

Most related projects present an underlying common aspect: the presence of multiple different devices, based on heterogeneous technologies, that need to be integrated according to specific user's and environmental needs. As a consequence, interaction among heterogeneous devices belonging to different networks (e.g., WLAN, PAN, cellular networks, etc.), and their coordination with an intelligent system, managed by doctors and operators, is one aspect addressed by current projects on assisted living and healthcare. Other projects focus more on the data management aspect, abstracting from networking aspects and addressing image processing, ontology management and user interfaces.

Few of these developed systems alert at an early stage when there is a change in behaviour that could lead to serious problems or an accident. In other words, prevention has not been fully addressed yet by existing technical solutions and detection of deviations in the personal behaviour is currently lacking. Furthermore, personalized support is limited only to selected domains and systems fail to seamlessly adapt to domain and patient conditions changes. In this context, ubiquitous computing presents an exciting challenge and a phenomenal opportunity. Proactive and wearable computing is a form of ubiquitous computing in which embedded systems anticipate the needs of people being around them and take the required actions thereby, enriching quality of life and engendering independence. Therefore, a new, scalable system architecture based on standards, which utilizes widely distributed semantically annotated data (sensor data, imaging data, genetic information, laboratory values, epidemiologic data, lifestyle information, family history, etc) and seamlessly integrate existing major information systems, is necessary.

The development of small and wearable sensor platforms from relatively inexpensive, commercially available components has created fascinating new opportunities for wireless health-monitoring. The sensor nodes can communicate wirelessly and have limited storage capabilities. The sensors measure variables including skin conductance, temperature, acceleration, and heartbeat. In most applications, a light-weight embedded sensor node is expected to acquire measurements, perform local processing and storage, and communicate over a short distance, for further processing. Despite their tremendous impact, these platforms, in terms of methodologies for hardware, software and signal processing design, are still at early stage. CHIRON, addresses this aspect by developing the hardware for the new sensor nodes, as well as the interfacing between sensor components and the local data processing. Thus, CHIRON patient monitoring capabilities present significant improvements over what is available in the state of the art. The final goal is to come up with an embedded device or system that measures simultaneously a number of simple parameters from easily applicable low-cost sensors, but that taken together form a powerful diagnostic tool. The combination of various parameters allows to improve the quality and robustness of each single indicator, thus enhancing sensitivity without causing false alarms.

Furthermore, currently available personal health monitoring solutions are "stand alone" systems and not part of a larger, more integrated healthcare system. CHIRON overcomes this problem by proposing a personal health platform, fully integrated into the clinical workflow and interconnected with the Hospital Information System. Data stored in the HIS and obtained from the conventional medical equipment are integrated with those gathered by the on-body sensor network. This will provide significantly richer information that translates in improved healthcare. A continuum of care will be enabled where the workflow is not limited to the hospital but is extended to other care centers, to the people's homes and to nomadic environments.

Moreover CHIRON realizes a multi-parametric approach in the monitoring by addressing the challenging issues related to sensor fusion and feature extraction from data of heterogeneous sources.

### B. USER PROFILING AND PERSONALIZATION IN THE DELIVERY OF HEALTHCARE SERVICES

A specific innovation of the CHIRON project is the management of the user profile; it evolves and automatically adapts over time to the user needs and to the changed context, by offering support independently of the particular domain in which the user is currently located. Such a profile represents an evolving model of the relevant aspects related to the health of a user and provides a continuously up-to-date risk assessment of the health status of the patient. Indeed, the profile evolution is a key concept,

as state-of-the-art projects foresee an intelligent system that represent the user profile, but that is updated by doctors, according to their knowledge of the user. This model allows to bring local intelligence close to the user. It does not only represent patient data and history, but also contains algorithms and rules that allow comparing monitored data with the user expected behaviour, resulting in a local alarm system. A functional health status part in this profile can for example provide valuable historic information and trend calculations on general activities and vital data that usually cannot be assessed in such precision and regularity in selective assessments at irregular points of time by physicians or caregivers. By this way automatic reaction on irregular trends can be enabled right in time to prevent critical situations.

Moreover the user profile will allow personalization in the delivery of the healthcare services. The "one size fits all" paradigm will no longer apply, especially when it comes to medicine. Personalization in medicine translates in personalized monitoring planning, personalized feedbacks, and personalized therapeutic treatments. It overcomes the drawback of current ICT-based Personal Healthcare Systems i.e., the missed personalized contact between the patient and his doctor.

### C. SENSOR NODES

In this area the advances over state-of-the art introduced by CHIRON are related to the enhanced capabilities of the nodes (low power design, energy harvesting with smart monitoring and management of the stored and generated energy and dynamic and adaptive energy saving strategies). Moreover the project aims at introducing innovative solutions in the monitoring of some parameters (both physiological and physical / environmental parameters):

- Multiparametric approach to non invasive blood pressure measurement;
- Blood serum potassium level measurements using the ElectroCardioGram (ECG);
- Extracellular fluid accumulation (peripheral edema) measurement using the ECG;
- Advanced positioning techniques where different technologies (RFID, WSNs, 802.11 APs) are combined for improved reliability and accuracy; and
- Sensors in the environment in addition to body-mounted or body-worn sensors to increase acceptance by elderly persons.
- Sophisticated signal processing and feature extraction algorithms to enhance the accuracy of the sensor's measurements in non ideal conditions such as those linked to the non-obtrusiveness of the used sensors and to the home environment (The research will adapt the monitoring technology valid in the clinical setting to the home care environment, by providing ease of use and suitable accuracy through the synergic monitoring of various parameters and the use of smart algorithms). The aim is to improve the quality and robustness of the indicator, thus improving sensitivity without causing false alarms.

### D. A novel solution for enhancing data security and privacy in the WSN and at application level

As already mentioned, **security** is a key element of business solutions often neglected in WSN projects (apart from selected projects such as UBISEC&SENS). The term security in the context of WSNs can be split up in several sub-topics, each investigating mechanisms rendering WSNs more secure.

- A first topic is the protection of the actual sensor node<sup>1</sup>. It embraces both secure hardware and secure software. Hardware protection includes basic cryptographic means, protection of memory like

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<sup>1</sup> Steffen Peter, Peter Langendörfer, Krzysztof Piotrowski Public key cryptography empowered smart dust is affordable Special issue on "Energy-Efficient Algorithm and Protocol Design in Sensor Networks", International Journal of Sensor Networks (IJSNet), 2008, Vo.3 No.5;  
Steffen Peter, Mario Zessack, Frank Vater, Goran Panic, Horst Frankenfeldt, and Michael Methfessel An Encryption-Enabled Network Protocol Accelerator 6th International Conference on Wired/Wireless Internet Communications (WWIC 2008), May 28-30, 2008 - Tampere, Finland;  
[L. Breveglieri, I. Koren, and P. Maistri. Incorporating error detection and online reconfiguration into a regular architecture for the advanced encryption standard. Defect and Fault Tolerance in VLSI Systems, 2005.;

balanced circuit avoiding leakages, and self diagnose-features that help to verify the current status of all connected components as well as its own physical conditions.

- In addition the protection of communication and interaction between the nodes is an important field. Secure communication in WSN<sup>2</sup> basically addresses secrecy of transmitted data, reliability of the transmission, robustness of protocols and specific security terms like authentication and non-repudiation.
- Data secrecy can be obtained with cryptographic protocols ( e.g. WSN related projects such as UbiSec&Sens and SMEPP have developed low power accelerators for cryptographic operations which can be used to ensure data integrity as well as confidentiality. Both projects have also done some investigations on the middleware and protocol parts. This comprises work on security configurations, secure protocols for routing and key distribution etc.).
- The question of secure software mainly addresses the operating system, middleware issues and how, and with which permissions, it executes the program code. First ideas on these challenges have already been published<sup>3</sup>.

As a result of these projects and of activities carried on by the research community in this active field complete protocol stacks are now available for a variety of possible applications. The energy consumption associated to the operation of such stacks has been significantly reduced over a few years ago.

In CHIRON - rather than aiming at coming up with new security means- our activities on security will advance the SoA by ensuring seamless integration of security features in an extremely heterogeneous environment. So our contribution will be

- Security architecture featuring:
  - Strong security on resource restricted devices such as wireless sensor nodes and within the well equipped hospital infrastructure.
  - Seamless integration of devices stemming from different administrative domains e.g. integration of user devices into the hospital architecture and vice versa.
  - End to end security in an environment which integrates heterogeneous communications technologies
- Privacy architecture which exploits the security architecture to ensure confidentiality of data and which allows to adapt the level of confidentiality of data according to external conditions such as type of diseases, role e.g. patient versus doctors/nurses.

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Harte, S., Rahman, A., Razeed K.M., Fault tolerance in sensor networks using self -diagnosing sensor nodes. IEE International Workshop on Intelligent Environments, 2005. University of Essex, Colchester, UK, June 2005

- <sup>2</sup> L. Buttyán, V. Gligor, and D. Westhoff (eds.), Security and Privacy in Ad Hoc and Sensor Networks, Lecture Notes in Computer Science No. 4357, Springer 2007.  
S. A. Camtepe, B. Yener, Key Distribution Mechanisms for Wireless Sensor Networks: a Survey, Technical Report, Rensselaer Polytechnic Institute, 2005.  
G. Ács and L. Buttyán, Secure Routing in Wireless Sensor Networks, In J. Lopez and J. Zhou (eds), Wireless Sensor Network Security, IOS Press, Cryptology and Information Security Series, 2008.  
F. Kuhn, T. Moscibroda, R. Wattenhofer. Fault-Tolerant Clustering in Ad Hoc and Sensor Networks, IEEE Conference on Distributed Computing Systems (ICDCS), 2006.  
L. Buttyán, P. Schaffer, and I. Vajda, CORA: Correlation-based Resilient Aggregation in Sensor Networks, Ad Hoc Networks, Vol. 7, No. 6, pp. 1035-1050, 2009.  
[Andre Weimerskirch, Dirk Westhoff, Stefan Lucks, Eric Zenner  
Efficient Pairwise Authentication Protocols for Sensor Networks: Theory and Performance Analysis, IEEE Press: Sensor Network Operations, IEEE Press Monograph, September 2004.  
P. Kamat, Y. Zhang, W. Trappe, and C. Ozturk. Enhancing source location privacy in sensor network routing. IEEE Conference on Distributed Computing Systems, 2005.  
L. Buttyán, T. Holczer, Private Cluster Head Election in Wireless Sensor Networks, IEEE Workshop on Wireless and Sensor Network Security (WSNS) Macau SAR, P.R.C., October 2009.  
A. Durrresi, V. Paruchuri, M. Durrresi, and L. Barolli. A Hierarchical Anonymous Communication Protocol for Sensor Networks. International Conference on Embedded and Ubiquitous Computing (EUC), Nagasaki, Japan, 2005.
- <sup>3</sup> L. Gu and J. A. Stankovic, t-kernel: Providing Reliable OS Support for Wireless Sensor Networks, ACM Conference on Embedded Networked Sensor Systems (SenSys), 2006.  
H. Kurth, G. Krummeck, C. Stüble, M. Winandy, M. Weber. HASK: Protection Profile for a High Assurance Security Kernel. Common Criteria V3.2 Protection Profile, German Federal Office for Information Security and Sirrix AG security technologies, December 2007  
P. Levis and D. E. Culler. Maté: a tiny virtual machine for sensor networks. In ASPLOS 2002, pages 85--95, 2002  
Langendoerfer, P.; Peter, S.; Piotrowski, K.; Nunes, R. J. C. and Casaca, A. A Middleware Approach to Configure Security in WSN, ERCIM Workshop on Emobility, Workshop Proceedings, ISBN: 978-972-95988-9-0, 2007

With regard to **privacy** whereas many privacy and data protection means aim at a declarative approach only, there are limited approaches for technical protection. To the best of our knowledge there are only a few approaches<sup>4</sup> that try to make sensitive data available to a third party while ensuring secrecy of that data.

The authors of [19] propose an architecture that ensures secure data processing by exploiting the Java sandbox model as an execution environment for data processing code and by limiting the feedback from the data processing code to the outside world. For correct interpretation of data processing results and the development of appropriate algorithms a part of the data has to be publicly accessible. In addition, sensitive data are always kept at its owner's site. The prerequisites of this concept render it impractical for implementation of location based or context sensitive services, although it is well suited for privacy preserving data mining.

The approach presented in [11] and in [20]<sup>5</sup> tries to make user data inaccessible outside a specially secured execution environment. User data are enclosed in an agent and securely transferred into an isolated, closed-door, one-way platform provided by a trusted third party. The service agents proceed analogously with their own data. These entire agents interoperate within the trusted environment and agree on a certain result. The result is forwarded by each involved agent to the closed-door platform, which posts the result to the agents' origins if the forwarded results are equal. This ensures that no private data is transmitted to the opposite party unless requested by the agent. All agents, together with their enclosed data, are deleted after service completion in order to ensure the privacy of the user and to protect the service's data. In a recent publication<sup>6</sup>, the authors describe the concept of a Privacy Guaranteeing Execution Container (PGEC) that does not rely on a trusted third party that provides processing capabilities, such as a server plus a specific agent platform. By design this container provides encapsulation of sensitive data and its deletion after service completion.

Basically the concept is that the application obtains access to the user data in a specially protected and certified environment, the PGEC. PGECs enable applications to access private user data and guarantee that the user data are deleted as soon as the service is quit. In a few words they guarantee a "one time use" of the provided private data. The PGEC also restricts the communication between the application and the service provider to what is explicitly allowed by the service user.

In Chiron we consider to adopt the Privacy Guaranteeing Execution Container (PGEC) to a low power portable device that could act as a data sink for a body area sensor network. That way we would enable a pre-processing of the arising data and a relevancy decision before sending it over a wide area network. Even anonymous studies and comparisons between various patients and treatment methods could be achieved within a network of containers. In addition, we consider adjusting the access rules for retrieving data out of the container by contextual information. That is, in urgent medical conditions such as emergencies, a treating cardiologist or other medical staff might access gathered data that were usually privacy protected.

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<sup>4</sup> Huda, N., Yamada, S., Kamioka, E.: Privacy protection in mobile agent based service domain. In: Proceedings of the Third International Conference on Information Technology and Applications (ICITA'05). Sydney (2005)

Yannopoulos, A., Stavroulasi, Y., Papadakis, N., Halkos, D., Varvarigou, T.: A method which enables the assessment of private data by an untrusted party using arbitrary algorithms but prevents disclosure of their content. In: P. Langendoerfer, V. Tsaoussidis (eds.) - Proceedings of the 3rd International Conference on Internet Computing. 3rd International Conference on Internet Computing, CSREA Press (2002)

U. Wilhelm, S. Staamann, and L. Buttyán, A Pessimistic Approach to Trust in Mobile Agent Platforms, IEEE Internet Computing, September-October 2000.

<sup>5</sup> Yamada, S., Kamioka, E.: Access control for security and privacy in ubiquitous computing environments. IEICE-Transactions on Communications E88-B(3), 846-856 (2005). DOI 10.1093/ietcom/e88-b.3.846

<sup>6</sup> Maaser, M., Langendörfer, P.: Privacy from Promises to Protection - Privacy Guaranteeing Execution Container. Mobile Netw Appl, Springer, 14:65-81 (2009), DOI 10.1007/s11036-008-0116-7

## E. MEDICAL IMAGING

CHIRON will develop:

- Advanced post processing techniques to get more quantitative information from medical images;
- Feature extraction, automatic detection and highlighting of suspicious regions of interest (ROIs) in the image and
- Innovative solutions of high dynamic range displays for enhanced visualization of the images.

The objective is to support the radiologists in their critical tasks by allowing more accurate diagnosis and reduced search and analysis time.

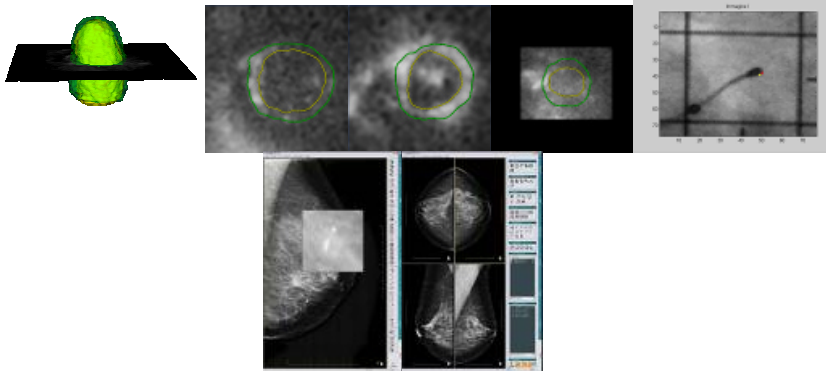
### E1. Advanced post-processing techniques for the extraction of quantitative information from medical images

In clinical practice the vast majority of measurements on medical images are performed manually or qualitatively. Moreover these measurements usually are limited to be linear or two-dimensional.

Actually, biomedical images contain information regarding biological structures, which are three-dimensional and time variant. Therefore, improved tools for quantitative (3D+t) analysis are nowadays requested. These tools will allow better description of the structures investigated by imaging, thus helping medical doctors in their activity.

In CHIRON we plan to develop innovative algorithms and tools for

- automatic detection of lesions in tissue images (CAD – Computer Aided Detection) (the algorithm will be based on a model of the lesions obtained by a set of features: shape, size, brightness, contrast, edge, ...);
- Quantification of natively 3D images and 3D data reconstructed from 2D images (segmentation algorithms);
- Quantification of parameters descriptive of biological structure motion (feature tracking, optical flow).



Medical images and advanced CHIRON solutions for post-processing and visualization

### E2. Visualization

In medical imaging a correct and fast diagnosis strongly depends on the performance of the display device used for the visualization of the image. For this reason, medical-grade display devices must satisfy strict quality requirements regarding for instance spatial resolution (pixels/inch), contrast ratio, brightness, grayscale response and grayscale resolution (bit depth)<sup>7</sup>.

The requirements of high resolution and high brightness, in particular, have favoured the widespread adoption of liquid crystal displays (LCDs), which outperform cathode ray tubes (CRTs) in these aspects. However, LCD displays still have a lower luminance range compared to the conventional radiographic film viewed on the light box, which typically reaches a peak luminance of 3000 cd/m<sup>2</sup> and a luminance range of

<sup>7</sup> See among the other references :

- American College of Radiology, "Practice Guideline for Determinants of Image Quality in Digital Mammography", 2007.
- National Electrical Manufacturers Association, "Digital Imaging and Communications in Medicine (DICOM). Part 14: Grayscale Standard Display Function", 2007.
- American Association of Physicists in Medicine Task Group 18, "Assessment of Display Performance for Medical Imaging Systems", 2005.

3 orders of magnitude<sup>8</sup>. In LCD displays the peak brightness (white level) is limited by technological constraints, regarding in particular the power consumption and the heat dissipation. The contrast ratio is also limited because the liquid crystal cells are not able to completely block the light coming from the backlight unit; therefore, a theoretically "black" pixel still exhibits a noticeable luminance. Moreover the bit depth and greyscale reproduction still represent a bottleneck: while digital x-ray detectors are already able to capture 12-bit or even 16-bit data, the pixels of LCD displays have an 8-bit depth (256 grayscale levels) that can be increased to 9.5 bit depth in monochrome LCD displays by using subpixel dithering techniques.

A high bit depth is desirable in order to reproduce a large number of distinct gray levels and allow the detection of small image's details which would otherwise be masked by the quantization noise.

These limitations often require the use of window and level adjustment techniques in order to reproduce all the image details adequately.<sup>9</sup>

CHIRON will propose an innovative LCD display structure obtained by stacking two liquid crystal panels one on top of the other. In this way, the light is modulated twice and the theoretical contrast ratio is squared for equal LCD panels. The bottleneck is that the intensity of the backlight unit must also be increased in order to compensate the additional light attenuation introduced by the second panel. Prototypes of "Dual Layer" LCD displays have been successfully built by FIMI Philips and are currently under development in cooperation with the University of Trieste. They are able to achieve a contrast ratio of over 50,000:1.

Moreover the dual layer technology is able to increase the grayscale reproduction accuracy because the light coming from the backlight unit is modulated twice by the two 8-bit liquid crystal cells.<sup>10</sup>

A dual layer LCD displays requires the use of complex "image splitting" algorithms in order to generate the two images which drive the two panels. The splitting algorithm should compensate different possible sources of errors, introduced for instance by a misalignment of the panels (due to construction tolerances and viewing angle) or by unwanted light scatterings between the panels. If an exact reproduction of the image is not possible, the algorithm should exploit the properties of the human visual system in order to minimize the visibility of the error.

In the CHIRON project the research activity will aim to move from the current prototype stage to the final production stage by addressing different issues still open such as the improvement of the splitting algorithm in terms of accuracy and computational efficiency, of processing times (to permit the display of video sequences) and its tuning according to the measured darkest levels and – from the hardware point of view - the efficiency of the backlight unit and its heat dissipation system. A further innovation will be the proposal of an extension of the DICOM GSDF (Grayscale Standard Display Function) applicable to the wide luminance range of the dual layer LCD display<sup>11</sup>.

In fact high dynamic range displays, based on the dual layer LCD technology, are able to reproduce luminance levels outside the interval for which the DICOM GSDF is defined, and in particular below the lower limit of 0.05 cd/m<sup>2</sup>.

Other innovative aspects we will explore are:

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<sup>8</sup> Currently available monochrome LCD displays have max luminance at level of 800 cd/sqm and a contrast ratio of approx. 1000:1, while for colour LCD displays the max brightness is at level of 400 cd/sqm.

<sup>9</sup> Window and level adjustment: the observer interactively selects an interval ("window") of gray levels, centered around a middle value ("level"); the visualization software then stretches the levels in the window to fill the entire luminance range of the display, clipping the levels outside the window. By changing the level and the window size, the observer can explore different portions of the image.

<sup>10</sup> Theoretically, 65536 different input combinations are possible; however, the corresponding output luminance levels are partially overlapped and irregularly spaced, and the splitting algorithm described in the following poses additional constraints. Therefore, the effective bit depth is lower than 16 bits.

<sup>11</sup> The quality of the displayed image, and consequently the accuracy of the diagnosis, strongly depends on the kind of mapping used to convert the input image data (typically a tissue density in case of radiography) into visible luminance.. One desirable property is that equal changes in the input density produce equal changes in perceptual brightness; a linear mapping does not achieve this goal due to the intrinsically nonlinear behavior of the human visual system (HVS). The DICOM Grayscale Standard Display Function (GSDF) defines a mapping curve based on an analytical model of the contrast sensitivity of the human eye developed by Barten.

- The adaptation of the grayscale mapping curve to compensate the ambient lighting and to guarantee in such a way a uniform visibility of the details<sup>12</sup> and to compensate for the effect of “veiling glare”<sup>13</sup> and
- the use of custom grayscale mapping curves based on the characteristics of the individual observer.

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<sup>12</sup> Amarpreet S. Chawla and Ehsan Samei, “Ambient illumination revisited: A new adaptation-based approach for optimizing medical imaging reading environments”, *Medical Physics* 34(1), January 2007.

<sup>13</sup> The presence of very bright and very dark regions in the same image can introduce a loss of detail visibility due to unwanted light scatterings inside the observer’s eye. This phenomenon is commonly known as veiling glare.