Convocatoria de ayudas a Proyectos de I+D
«EXCELENCIA»
SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO
2013

MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS INDIVIDUALES (TIPO A o B)

INSTRUCCIONES PARA COMPLETAR LA MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS DE I+D DEL SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO (PROGRAMA ESTATAL DE FOMENTO DE LA INVESTIGACIÓN CIENTÍFICA Y TÉCNICA DE EXCELENCIA)

Lea detenidamente estas instrucciones para completar correctamente la memoria-científico técnica.

1. Este modelo de memoria está restringido en su extensión máxima y por consiguiente ha de limitarse a los espacios indicados al completarla.
2. Las memorias pueden completarse en español o en inglés, a excepción del apartado 1. RESUMEN DE LA PROPUESTA, que debe completarse en ambos idiomas.
3. Se recomienda completar la memoria empleando un pc con sistema operativo Windows y usando como procesador de textos MS Word (MS Office).
4. Para completar los textos, sitúe el cursor en las zonas sombreadas. 4000 caracteres son, aproximadamente, una página.
5. Una vez terminada la memoria, guarde su archivo en formato pdf (de no más de 4Mb) y apórtelo a la solicitud telemática del proyecto en el apartado “Añadir documentos”.
6. Debido a que este formulario está diseñado para incluir únicamente texto con un tipo de letra determinado, si necesita incluir fórmulas, reacciones químicas, fórmulas matemáticas, etc., o figuras aclarativas, deberá hacerlo en los anexos I y II, respectivamente, tras citarlas en el cuerpo del texto. No deberá emplear más extensión que la indicada.
7. El formulario está adaptado para poder emplear la opción de “copiar y pegar”.

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AVISO IMPORTANTE

En virtud del artículo 11 de la convocatoria **NO SE ACEPTARÁN NI SERÁN SUBSANABLES MEMORIAS CIENTÍFICO-TÉCNICAS** que no se presenten en este formato.

1. RESUMEN DE LA PROPUESTA / SUMMARY OF THE PROPOSAL

(Debe rellenarse también en inglés / It should also be completed in English)

INVESTIGADOR PRINCIPAL 1 (Nombre y apellidos)**:**

VICENTE MORET BONILLO

INVESTIGADOR PRINCIPAL 2 (Nombre y apellidos)**:**

NO

TÍTULO DEL PROYECTO:

ANALISIS INTELIGENTE DE SEÑALES NEUROLOGICAS Y CONSTRUCCION DE HIPNOGRAMAS PARA DETECCION E INTERPRETACIÓN DE EVENTOS EN SINDROME DE APNEA EN SUEÑO.

ACRÓNIMO:

HYPNOGRAM

TITLE OF THE PROJECT:

INTELLIGENT ANALYSIS OF NEUROLOGICAL SIGNALS AND HYPNOGRAM CONSTRUCTION FOR EVENTS DETECTION AND INTERPRETATIONS IN THE SLEEP APNEA SYNDROME.

ACRONYM:

HYPNOGRAM

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RESUMEN

Debe contener los aspectos más relevantes, los objetivos propuestos y los resultados esperados.

El resumen del proyecto debe completarse también en la aplicación de la solicitud. Su contenido podrá ser publicado a efectos de difusión si el proyecto resultara financiado en esta convocatoria.

Máximo 3500 caracteres

En el ámbito de las patologías del sueño, la polisomnografía (PSG) es una técnica consistente en el análisis de diversas señales biomédicas del paciente, tales como la actividad cerebral y cardiaca, los movimientos oculares y los musculares, el flujo respiratorio, además de otro tipo de señales que representan información de contexto. La realización de esta prueba presenta, no obstante, algunos inconvenientes: es cara, es incómoda para el paciente y los resultados son difíciles de interpretar. La interpretación correcta de una prueba polisomnográfica debería permitir determinar la ocurrencia de posibles eventos apneicos, confirmar tales eventos como apneas o hipopneas en el contexto de la fase de sueño del paciente, y una vez confirmados los episodios correspondientes, clasificarlos correctamente como obstructivos, centrales o mixtos. Los propios expertos suelen discrepar a la hora de interpretar los resultados de una prueba polisomnográfica. Algunas de las causas de estas divergencias son: la dificultad inherente al registro de las señales fisiológicas y su posterior tratamiento, lo incompleto y ambiguo del conjunto de criterios establecidos como estándar para la clasificación del sueño, o la carencia de unas líneas de definición claras y ampliamente aceptadas para la caracterización de los eventos apneicos. Todo ello se refleja en el carácter heurístico del conocimiento empleado por los clínicos para emitir su diagnóstico, en el empleo de terminología cualitativa, y en la naturaleza tanto numérica como simbólica de la información manejada. A todo esto se une la necesidad de contextualizar la interpretación, relacionando el proceso de sueño con la fisiología respiratoria y ésta con las características propias del paciente. La posibilidad de efectuar un tratamiento off-line de la información, de dividir el problema en subproblemas y establecer taxonomías entre conceptos y procedimientos, justifican la conveniencia de desarrollar un sistema de monitorización inteligente para la ayuda al diagnóstico, basado en la aplicación de técnicas de inteligencia artificial. Al respecto, la identificación de fases del sueño es una de las tareas más importantes en el contexto de los estudios del sueño realizados mediante polisomnografía. El principal objetivo de la identificación de fases del sueño es la construcción del hipnograma, un resumen del sueño del paciente clasificado por fases. La correcta construcción del hipnograma servirá para mejorar la detección de los eventos relacionados con los trastornos de sueño y poder así realizar un diagnóstico preciso, lo que sin duda permite optimizar la terapia oportuna. Con la realización de este proyecto se pretende el desarrollo de un sistema inteligente capaz de identificar y clasificar correctamente las distintas etapas por las que transita el sueño de un paciente monitorizado con polisomnografía en una unidad de sueño, o en proceso ambulatorio, utilizando para ello razonamientos de lógica difusa para obtener de este modo una salida continua en la que se pueda observar la evolución real del sueño del paciente. En todo caso queda todavía mucho trabajo de desarrollo de nuevas técnicas y aproximaciones para lograr una representación adecuada de la macroestructura del sueño. La inclusión de este módulo inteligente clasificador del sueño del paciente en un sistema integrado supondría la obtención de un producto perfectamente autónomo y potencialmente listo para su comercialización inmediata.

PALABRAS CLAVE

Máximo 200 caracteres

Sistemas de Ayuda a la Decisión en Medicina, Monitorización Inteligente.

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SUMMARY

It should contain the most relevant topics of the project, the objectives and the expected results.

The summary should also be completed in the electronic application. It could be published for diffusion purposes if the project is financed in this call.

Maximum 3500 characters

In the field of sleep disorders, polysomnography is the technique of analysis of various biomedical signals of the patient, such as heart and brain activity, eye movements and muscle tone, the respiratory flow, in addition to other signals representing contextual information. The completion of this test show, however, some drawbacks: it is expensive, it is uncomfortable for the patient and the results are difficult to interpret. The correct interpretation of polysomnographic records should allow to determine the occurrence of possible apneic events, confirm events such as apneas or hypopneas in the context of the sleep phase of the patient, and -once confirmed- properly classify such events as obstructive, central or mixed. The experts tend to disagree when interpreting the results of a polysomnographic test. Some of the causes of these differences are: the difficulty inherent in the recording of physiological signals and the subsequent treatment of the incomplete and ambiguous set of standard criteria for the classification of sleep, or the lack of clear lines of definition and widely accepted criteria to characterize the apneic events. This is reflected in the nature of the heuristic knowledge used by clinicians to make the diagnosis, the use of qualitative terminology, and in both the numeric and symbolic nature of the handled information. The above mentioned problems should be faced taking into account the needs of contextualizing the interpretations, as well as of relating the process to sleep and respiratory physiology with the characteristics of the patient. The possibility of an off-line processing of information, and also the possibility to divide the problem into subproblems and taxonomies between concepts and procedures, justify the desirability of developing an intelligent monitoring system for the diagnosis, based on the application of artificial intelligence techniques. In this regard, the identification of the sleep phases is one of the most important tasks in the studies conducted by sleep polysomnography. The main objective of the identification of sleep stages is the construction of the hypnogram: a summary of the sleep stages and of the sleep macrostructure of the patient. The correct construction of the hpnogram is crucial to improve the detection of events related to disturbed sleep and thus make an accurate diagnosis, which undoubtedly allows appropriate therapy. With the completion of this project, the main purpose is to develop an intelligent system able to correctly identify and classify the different stages through which evolve the sleep phases of a patient monitored with polysomnography either in a sleep unit or an outpatient clinic, thereby using fuzzy reasoning to get a continuous output in which to observe the evolution of the real sleep of the patient. However, much effort has to be done to develop new techniques and approaches to obtain a good representation of the sleep macrostructure. The inclusion of this new intelligent sleep classifier as a contextual module for an apnea monitor in an integrated system would obtain a perfectly independent system and potentially ready for immediate launch.

KEY WORDS

Maximum 200 characters

Medical Decision Support Systems, Intelligent Patient Monitoring

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2. INTRODUCCIÓN

2.1. Antecedentes y estado actual de los conocimientos científico-técnicos de la materia específica del proyecto, incluyendo, en su caso, los **resultados previos** del equipo investigador, de otros grupos que trabajen en la misma y la relación, en su caso, entre el grupo solicitante y otros grupos de investigación nacionales y extranjeros;

- si el proyecto es continuación de otro previamente financiado, deben indicarse con claridad los objetivos y los resultados alcanzados de manera que sea posible evaluar el avance real que se propone en el proyecto solicitado.

- si el proyecto aborda un nuevo tema, deben indicarse los antecedentes y contribuciones previas del equipo investigador con el fin de justificar su capacidad para llevar a cabo el nuevo proyecto.

Máximo 16 000 caracteres

Having a good understaing of the macrostructure of sleep trhough the so-called HYPNOGRAM is crucial in the diagnosis of the Sleep Apnea Syndrome (SAS) also named Sleep Apnea/Hypopnea Syndrome (SAHS) The procedure for obtaining the hypnogram was initially proposed in 1968 by Rechtschaffen and Kales (R&K). R&K method establishes a set of rules to assign to a given time interval in the Polysomnogram (PSG) a label representing certain state of sleep: Wakefulness (W), stages 1 to 4 -Light Sleep to Deep Sleep- (S1, S2, S3 and S4), and Rapid Eye Movement (REM) phase. Therefore the sleep recording is segmented into these classifiable intervals, called epochs, being its length usually established to 30 seconds. Sleep states are then assigned based on the trend of the signals within the epoch, which following the R&K method involve monitoring of brain activity by Electroencephalography (EEG), characterization of muscle tone by Electromyography (EMG) and localization of eye movements by Electooculography (EOG).

R&K method has been the gold standard for the scoring of sleep macrostructure for more than 40 years, being only recently modified by the American Association of Sleep Medicine. Sleep staging is in general a tedious task entailing too much time and effort for the physician, requiring around 5 hours per patient examination. Automatic sleep scoring should help to reduce the time needed by the physician to construct the hypnogram and, accordingly, attempts to develop automatic sleep scoring are almost as old as the R&K rules. Literature provides with several examples of approximations involving different techniques: pattern recognition, evidential theory, probabilistic models, stochastic modeling of physiological feedback structures, artificial neural networks or wavelets. A detailed review of the literature demonstrates, however, that automation of hypnogram generation is still an unresolved problem, as well as an open area of interest.

On the other hand in the recent years several criticisms have been associated with such a method of sleep characterization. Major drawbacks are associated with its low temporal resolution –one label for 30 seconds- and the unnatural classification of sleep based on fixed-duration discrete epochs. Effectively, evolution of biological processes rather occurs in a continuous manner in which a soft transition takes place between the different considered states. Moreover, restriction of the analysis to a small number of sleep states and the use of fairly large epochs lengths, seems to obey more to practical criteria to avoid the manual scoring of an entire night's sleep to be a prohibitively time consuming task. However such a restriction is at the cost of an increase in the intra-state variability and information lost, which nowadays is summarized under the broad level of microstructure of sleep, including microarousals, sleep spindles, k-complexes and any other activity with latency shorter that the half-minute of the epoch-based staging methodology.

On this context, there is an interest on exploring different approaches that could overcome these limitations. Specifically, it is interesting to develop computer approximations on the goal of achieving a more continuous characterization of sleep. Thereby avoiding the limitations of sleep staging previously outlined. For example, a guideline to this effect has been proposed as part of an European Community concerted action towards a methodology for the analysis of the sleep/wakefulness as a continuum.

In the line through the achievement of a continuous marker describing the sleep structure some approximations can be found in the literature. In this respect a first interesting step is to obtain a continuous sleep depth estimator. Some examples can be found in the contributions of M.H. Asyali, Choi, Swarnkar, Saastamoinen. However previous approaches suffer from the lack of information on the intra-sleep periods. A realization that could also account for a continuous characterization of no REM (NREM) intra-states is desirable. A. Flexer et al. developed a continuous probabilistic sleep stager (considering three states: wakefulness, deep sleep and REM) based on a single EEG signal.

Nevertheless a problem with probabilistic approximations is that they assign one minus the probability of an event to the complement of the event, i.e. there is no possibility of differentiating between uncertainty about an event and the probability of its complement. On the other hand, the fuzzy paradigm presents an important property to allow the continuous representation of biological processes: soft transitions between class memberships, i.e. fuzzy classifiers yield similar outputs for similar input patterns. This approach is investigated in the work of Heiss et al. but, however, it contains some drawbacks with respect to our approach, mainly: (1) it is focused for its use on infants and, (2) it uses the architecture ANFIS in order to implement the fuzzy classifier and to represent the knowledge of the domain. Indeed, to fulfill the requirement of a system being able to explain its results, there is an additional property a system for medical decision support should satisfy: the system should not be a black-box, it should be possible to check why and how a certain recommendation is given. In this respect, the ANFIS structure can be considered more as a special kind of neural network since the use of Sugeno-like rules considerably reduces explanation capabilities.

Although compared with other automatic detection systems, computer systems for the analysis of sleep structure and diagnosis of its diseases may not had had a great historical demand in medicine, this trend has radically changed over the last few years. That is in great part because of the emerging importance that today is given to a good nocturnal rest, as a fundamental factor for the developing of a full and satisfactory daytime life. In the following some of the most relevant commercial systems are introduced, together with a brief description of their capabilities. It does not attempt to be much less an exhaustive enumeration, but we present here a summary of the current possibilities of these systems.

1.PolySmith, Neurotronics, Nihon Kohden, USA. PolySmith is software for recording and reviewing sleep data files.

2.Somnolyzer 24x7, Royal Philips Electronics, The Netherlands.Software Somnolyzer 24x7 is the resulting software produced by the The Siesta Group initiative which was recently acquired by Philips.

3.Aura Lab-based PSG, Grass Technologies, USA. Equipment Aura of Grass Technologies company allows the technician the realization of polysomnographic tests either ambulatory or hospital attended.

4.Somnostar 4100, Sensormedics Corporation, USA. It records signals of EEG, EOG, EMG, ECG, digital pulse oximetry, thoracic and abdominal movements, body position and oro-nasal flow.

5.Polyman, Bob Kemp and Marco Roessen, The Netherlands. Polyman is not strictly speaking commercial software for the automatic analysis of sleep but an EDF/EDF+ viewer and sleep scoring supporting program that was created by Marco Roessen and Bob Kemp.

Nevertheless, with regard to their data analysis capabilities, such systems still continue to present several shortages, and in most of the cases, the manual method is yet used to perform the analysis of the PSG. There exist therefore an intense interest in the development and the continuous improvement of the analysis capabilities of the systems aiding in the SAHS diagnosis. Besides, additional research lines come up attempting to simplify the standard analysis method. Among all these approximations which are aimed at overcoming the drawbacks of current commercial systems, either augmenting their features or innovating in the use of new diagnostic techniques, there can be found those here referred as non commercial or academic approximations.

In this respect, it is rare the research line that pursues the construction of a complete system from the scratch. Instead, at this level one usually finds attempts of innovation with regard to specific tasks within the general diagnostic approach or alternative methods aimed at substituting –by normally simplifying- the current PSG analysis procedure. Within this group we firstly cite the system ISAS developed at INESCN and that it has been validated at hospital Santo Antonio de Oporto. Another interesting development is the system PSG-EXPERT, which is presented as the particularization for the case of SAHS of a more general integrated environment for the development of diagnostic expert systems. From an application point of view, PSG-EXPERT is defined as an auxiliary diagnosis system for sleep disorders based on polysomnographic data. Such data are extracted through a series of processings and are inserted in a database organized according to the following categories: clinical history, hypnogram data, sleep parameters, spectral data, EEG time related activity and non EEG activity.

The design and implementation of an intelligent diagnostic system for SAHS aimed at solving the problems of their preceding systems, as well as improving their capabilities, was the object of the doctoral thesis of Elena Mª Hernández Pereira -directed by the IP of this project- , member of the LIDIA group, and also one of the researchers in this project. The result of her investigation is the system MIDAS which later evolved into the SAMOA system. SAMOA, unlike in other systems, integrates both artificial intelligence techniques for the development of reasoning processes over well-known rules, and classical techniques of signal processing and software engineering, for the development of an integrated product which, besides, it is able to provide explanation of its results. A common drawback of current available systems, including MIDAS and SAMOA is that analysis processes are handled from an excessively quantitative perspective, not accounting for methods to handle imprecision. In addition, it is usual within the clinical language, to express opinions in terms of possibilities rather than in terms of certainties, possibilities over which it is thought more in qualitative than in quantitative terms.

In this context our most recent approach in the field of Sleep Medicine is the Intelligent System MIASOFT developed by Diego Alvarez in his doctoral thesis -directed by the IP of this project- . MIASOFT is an integrated software for intelligent monitoring of SAHS and it is the result of fifteen years of funded research. The developed program analyzes the signals monitored in patients undergoing nocturnal polysomnography: mainly signals related to the patient's respiratory function, but also those related to the patient's sleep. However, much effort still needs to be done in order to achieve a good representation of the patient sleep macrostructure. In particular:

IMPROVING MIASOFT:

The EOG is one of the signals used for the construction of the hypnogram. Initially it worked extracting the amplitude and using it for diverse calculations inside the algorithm. However the detection of phase REM is not satisfactory. Efforts need to be done in looking for alternative techniques that improve the detection of phase REM by means of the EOG.

Also, for the detection of some events it is necessary to consider sleep spindles and k-complexes. One of the greater difficulties of these events is in the lacking of standard criteria for signals correlation. For this purpose it is necessary to develop new algorithms.

Basic Research and Signals Prediction:

The idea consists basically in trying to predict signal evolutions by means of artificial neural networks (ANN). Patient is used to have a natural evolution, as long as there are not interruptions caused by external agents or illnesses (apnoeas). Incorporating ANNs that analyse this evolution could improve the decision tasks in atypical cases and so detecting anomalies in the patient sleep.

Also, detection of “Dientes de Sierra” –spikes- and other characteristic signals is important. Apart from the basic concepts of the sleep phases there exist patterns of signals that doctors observe in a lot of patients and that help them to improve the classification of sleep phases. Specifically, “Spikes” are very common and characteristic. In this respect, our purpose is to develop algorithms able to detect these patterns and to find the correlation with the sleep phases.

International Cooperations

The team applicant of the present project keeps an intense and fruitful collaboration with the group of Dr. Bob Kemp (NL), and we pretend to continue keeping such a collaboration. Said team works in a very similar line to ours, and one of our recently formed doctors (D. Alvarez) is at present working in the laboratory of Dr. Kemp.

Also we work of narrow way in the fields of signal processing, ANNs and machine learning, with the team of Prof. Principe, of the University of Florida, Distinguished Professor, BellSouth Professor, Director of Computational NeuroEngineering Laboratory, and IEEE Fellow, and we have co-authored several publications.

In the field of biomedical engineering we keep, from 1990, a narrow research relationship with Prof. Kerkhof (Amsterdam, NL), materialised in several publications of which stand out the chapter entitled: Medical Expert Systems, written for the Webster Encyclopedia (John Wiley, eds.)

Finally, and in the international field, stand out our collaboration with Case Wertern Reserve University (U.S.) and with John Hopkins University through the consortium Sleep Health Heart Study (SHHS), to which our team belongs.

PREVIOUS RESULTS (Selected Publications)

1. A method for the automatic analysis of the sleep macrostructure in continuum. D Álvarez-Estévez, JM Fernández-Pastoriza, E Hernández-Pereira, V Moret-Bonillo. Expert Systems with Applications 40(5), 1796-1803, 2013.

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2.2. Bibliografía más relevante.

Máximo 8000 caracteres

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2.3. Finalidad del proyecto, oportunidad de llevarlo a cabo y adecuación del mismo a la Estrategia Española de Ciencia y Tecnología y de Innovación y, en su caso, a Horizonte 2020 o a cualquier otra estrategia nacional o internacional de I+D+i.

Máximo 8000 caracteres

The Spanish Strategy of Science and Technology and of Innovation looks for the diffusion of the profits generated by the scientific and technical knowledge, its practical application and its social diffusion as well as by the generation and adoption of key innovations for the modernisation of the country.

In concrete, it favours the activities of R & D oriented to the global challenges of the Society and especially to those that affect to the Spanish society. These challenges, by his nature and complexity, do necessary intend to combine the generation of new knowledge, with his application to technologies, products and services that in a future can contribute to the scientific leadership, technological and business of the country.

The general purpose of the Spanish Strategy of Science, Technology and of Innovation is to promote the scientific leadership, technological and business lines of the country and strengthen the capacities of innovation of the society and the Spanish economy, for which establishes the application of criteria of quality and importance and social impact internationally recognised in the allocation of the competitive public resources destined to the promotion of the activities of R & D. It pretends the definition of some favourable surroundings that facilitate the development of the activities of R & D and it allows the creation of a flexible and efficient frame in the field of the public R & D and exploitation of results that are adapted to the needs of the agents, and promotes the impulse to the specialisation and aggregation in the generation of knowledge and talent that achieve a clear division of functions between the agents to facilitate the international leadership in R & D so improving the complementarity of the activities. Likewise it stimulates the transfer and management of knowledge in open and flexible surroundings of collaboration in R & D in which the interaction, the diffusion of ideas, and the adoption of common goals and models favour the development of new ideas and incentive their transference to new applications both commercial and non commercial thus allowing improvement of the results obtained. The support to the internationalisation and the promotion of the international leadership of the Spanish System of Science, Technology and Innovation are fundamental factors, since they constitute a clear factor of competitiveness and differentiation that is necessary to improve. In this context, we consider timely to perform the following analysis:

A. SOCIAL IMPACT: The sleep apnoea/hipopnea syndrome, SAHS, is an illness very prevalent that affects to the 1-3% of the childish population, to the 4-6% of the men and to the 2-4% of the women in the adult general population, and its prevalence increases clearly with age. It has been demonstrated that the SAHS is associated with the deterioration of the quality of life, arterial hypertension, development of cardiovascular and brain illnesses and traffic accidents. Besides, there is an increase of mortality associated to the SAHS. On the other hand, it has of effective treatments. Thus, and considering the medical complications of the SAHS, as well as the social and laboral repercussions and its negative impact in the quality of life and survival, it can be concluded that this illness is a problem of public health that forces to the doctor to identify the subsidiary patients of treatment. In fact, it has been checked that not diagnosing and treating the patients with SAHS supposes a consumption of resources unacceptable from both economical and social view points. The SAHS is a problem of public health of first magnitude that still has not been resolved. In a society advanced as ours it does not result coherent to have diagnosed and treat less than 10% of the population suffering from SAHS. The future of the diagnostic of the SAHS goes through the research of systems extraordinarily simple in its handling and application, that can be employed by personnel with no particular expertise, although the internal structure of such systems are of big complexity. The fact of having expert technology that can be handled by non-experts will be fundamental in order to tackle the process diagnostic of the patients, not only by the skilled personnel in the sleep laboratories, but also by doctors of primary attention that will have to participate in the diagnostic and in the treatment and control of the patients with SAHS.

B. TRANSVERSALITY: It is an essential characteristic of this project that involves multidisciplinary knowledge and interdisciplinarity on fundamental aspects of Neurology, Sleep Medicine, Signal Processing, Artificial Intelligence, Advanced Reasoning, Knowledge Engineering, Software Engineering, and Specific Techniques for Validation and Usability. This transversality is a characteristic that favours the development of sinergies and the constitution of research teams highly qualified, as it is the case of this project, in which most of the members that appear in the proposal are doctors, some of them of enormous international prestige and leadership in their respective fields.

C. INTERNATIONALISATION AND LEADERSHIP: In the working team of the project object of the present application participate researchers of great impact and international relevance that develop their research in three different countries: 1.Spain, that leads the project from the UDC, 2.Holland, that contributes in diverse fields of Biomedical Engineering -Prof. Kerkhof & Prof. DeMunck (Collaborating Professors)- Neurology & Computer Science -Profs. Kemp & Alvarez (Collaborating Professors)-, and 3.The United States, that contributes through Professor Principe (Collaborating Professor) in questions related with signals processing)

The centres involved in this project are:

a. Laboratory of Research and Development in Artificial Intelligence, a research group of the Department of Computation of the Universidade Da Coruña (UDC). The members of LIDIA develop educational and R & D activities in both theoretical and practical aspects of Artificial Intelligence from the year 1990. In the field of health, LIDIA has centered efforts in: Decision helping tools for the prescription and personalised supervision of physical activity, Diagnosis and prognosis of antenatal state, Telemonitoring, Diagnosis and classification and monitoring of patients with SAS, and Intelligent Monitoring of patients in Intensive Care Units.

b. Sleep Centre, MCH - Westeinde Hospital, Den Haag, The Netherlands. The sleep center examines and treats adults and children with SAS. A specialized medical team first bring sleeping problems precisely map. For this purpose, the sleep center has a wide range of research methods. The treatment team then provides a treatment. The sleep center conducts research which is constantly working to improve the diagnosis and treatment of sleep disorders.

c. VU MEDISCH CENTRUM Amsterdam, The Netherlands. The research of VUMC is dedicated to five focus areas: cancer & immunology, neurosciences, cardiovascular disease, public health, primary care & long-term care and movement sciences. Its research is part of the VU campus Human Health & Life Sciences theme, and it is organized in five multidisciplinary research institutes.

d. Computational Neuroengineering Laboratory CNEL. University of Florida, USA. CNEL research explores the principles that guide the ability to comprehend brain function, treat brain disorders, and ultimately to interface directly with the brain. Their researchers combine principles from machine learning, signal processing theory, and computational neuroscience to advance the science of engineering systems.

D. CONCLUSION: In accordance with the description and analysis that has been exposed, we consider that the present project fits perfectly into the methodology and planned aims and goals of the Spanish Strategy of Science and Technology and of Innovation 2013-2020.

Convocatoria de ayudas a Proyectos de I+D
«EXCELENCIA»
SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO
2013

MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS INDIVIDUALES (TIPO A o B)

3. HIPÓTESIS Y OBJETIVOS DEL PROYECTO

Describa las razones por las cuales se considera pertinente plantear esta investigación, **la hipótesis de partida y los objetivos generales** perseguidos. Enumere brevemente, con claridad, precisión y de manera realista (acorde con la duración prevista del proyecto), los **objetivos específicos** que se persiguen con indicación expresa del investigador principal (IP) responsable en aquellos proyectos con dos investigadores principales.

Máximo 8000 caracteres

The basic hypothesis that support the realisation of this project resides in the high degree of imprecision that at present can be found in the systems of identification of sleep phases. In this context, the identification of the sleep phases is one of the most important tasks in the studies of SAS. Our main objective is the development of techniques helping in the diagnosis of SAS, which will contribute to solve the problems of current approaches for the automatic analysis of the PSG. An important source of information for the interpretation of the apneic events is given through the hypnogram of the patient. In this context an important rule of interpretation to be taken into account is that, by definition, the occurrence of an apneic event must occur while the patient is asleep. Therefore all those reductions in airflow localized in the periods where the patient is awake (stage W in the hypnogram) should be discarded as being effectively caused by the occurrence of an apneic event. Besides, it is important to bear in mind that during wakefulness the monitored patient tends to make the normal movements of a waking person. That introduces lots of possible artifact sources which may look like neumological airflow reductions but, logically, they do not have an apneic origin. Thus, it is evident that not discarding these false positives will considerably overestimate the presence of SAS in the patient. Another important context of interpretation derived from the hypnogram of the patient has to do with considering the different sleep stages in which the reduction in the airflow takes place. In this respect it is known that respiratory activity becomes more unstable during REM sleep. Additionally, it has to be added that muscular relaxation associated to REM stage favors the collapse of the upper airways, which makes REM sleep to be a period with a special prevalence of apneic events. For this reason which in another situation could be considered as an abnormal behavior of the respiratory signals, it can be normalized taking into account the context of REM occurrence in the hypnogram. There are some other cases, such as the transition form a light sleep state to deep sleep, where a slightly reduction in the respiratory signal is normally produced. In this case however the reduction should be related with the phase transition, not being attributed to occurrence of an apneic event. Also related with sleep structure but rather connected to at its microstructure level, is the occurrence of EEG arousals that constitute another factor of interest for the detection of apneic events. In this regard detection of micro-arousal events may result a neurophysiological evidence of the immediately previous occurrence of an apneic event in the neumological signals. According with the last review of standards for detection and classification of apneic events, the presence of EEG arousal may be required in order to confirm the existence of a hypopneic event type. According to this the developed techniques should include the analysis of the electrophysiological signals related to sleep. In this manner the system will perform an analysis of the electroencephalography (EEG), electrooculography (EOG) and submental electromyography (EMG) to obtain the structure of the patient's sleep or hypnogram. Besides, during the EEG analysis a detection of transient events such as sleep spindles, K-complexes or EEG arousals will be performed. All of these events are subsequently correlated in time, and will be interpreted in the context of the neurophysiological signals. Another goal is that of linking the apneic events causing EEG arousals to their corresponding neurophysiologic event, thus allowing the determination of the cause-effect relationship between the apneic event, and its associated microarousal. The developed approach will also take into account the presence of possible artifacts in the monitored signals. One of the main contributions of this project lies in the incorporation of mechanisms supporting imprecision in the data, and the capacity to establish reasoning processes affected by uncertainty. More specifically such procedures are supported by the prominent use of artificial intelligence techniques based on the fuzzy analysis of the information. Such capabilities contribute, on one hand, to the improvement of the results in the presence of noise at the input. On the other hand, they contribute to augment generalization capabilities of the system, thus reducing somewhat the effective variability of the results. Traditionally structural analysis of sleep is carried out from the PSG based on three fundamental sources of information which defines it from a physiological point of view: EOG, EMG and EEG, which in the literature can also be found abbreviated as EXG. The popularization of this set of signals dates back to 1968 when a committee co-chaired by Rechtschaffen and Kales (R&K) published “A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects”. It was only recently when the AASM proposed a modification of the scoring method. The new manual was published in 2007 aimed at giving a response to the advancing of sleep science, incorporating evolutionary changes as well as newer technical methods and capabilities. In general, the rules and specifications for the scoring of sleep retain much of the framework of R&K, based on the accumulated validity and reliability of this scoring system, with some new definitions and rule modifications, as well as with new rules for pediatric visualization. Arousals, movements, respiratory events and cardiac events are now included into the standardized scoring system. However, the new AASM manual can be considered in many senses more as a specification over the R&K method, rather than a new method itself. Some other modifications include new recommended derivations for the EEG scoring. They exist situations where the identification of events is simple, even with an alone signal, but the true problem of this task is in the garbled situations caused events associated to disorders of the sleep, or a zone of change of phase, that's why in our approach we will analyse the whole set of signals to have the greater possible information of each moment of the patient sleep with the purpose of minimizing the number of errors. Once identified the sleep phases it is necessary to assign, for each epoch, the sleep stage of the patient. When the analysis of the signals is finished the analysis the system will give back the hypnogram as the final product. Besides, also it will show the process of reasoning by means of which the "decision" has been taken, so that the expert will be able to see the corresponding sleep phase (that of greater possibility), together with the confidence values of the remaining phases.

From a technical viewpoint and complementing the fuzzy logic approach for handling imprecision, efforts need to be done in the following key areas: Data input, machine learning models, temporal correlations and reasoning and non-linear dynamic systems.

According to this general outline, the specific goals contemplated in this project are the following:

Goal Number 1. Design and implementation of the necessary software for the correct identification of the cerebral activity of a patient subjected to nocturnal PSG.

Goal Number 2. Design and implementation of the necessary software for the correct classification of the cerebral activity of a patient subjected to nocturnal PSG in sleep phases.

Goal Number 3. Design and implementation of the necessary software for the documented construction of the hypnogram of a patient subjected to nocturnal PSG.

Goal Number 4. Validation of the software developed.

Goal Number 5. Systematic analysis of the Usability of the system developed.

Goal Number 6. Definition of a strategy for commercial exploitation of the product developed.

4. METODOLOGÍA, PLAN DE TRABAJO Y RESULTADOS PREVISTOS

4.1. Descripción de los **materiales, infraestructuras y equipamientos singulares** a disposición del proyecto que permitan abordar la metodología propuesta.

Máximo 4000 caracteres

The research group involved in this project is the biomedical and symbolic artificial intelligence branch of the Laboratory for Research and Development in Artificial Intelligence (LIDIA) of the University of La Coruña (UDC). LIDIA is included in the catalogue of Groups of Excellence of the Galician Autonomous Community and in the program of Structuring and Consolidation of Groups of Competitive Reference, that the Xunta de Galicia concedes in diet of competitive concurrence to reward the research of excellence. As a consolidated research group, LIDIA has of two well equiped laboratories, one in the Faculty of Informatics of the UDC and another in the Centre of Investigation in Technologies of the Information and the Communications (CITIC). For the development of this project we have computing resources and the infrastructure of communications provided by RedIRIS. The equipment hardware for this project features of 8 desk computers of last generation, a server of applications, a network with storage capabilities, 3 laser printers and 1 backup server. In addition to our own developed programs (e.g., registered software for validation and usability), available software includes desk applications for development of algorithms, visualization of data, analysis of data and numerical calculations. We also have access to diverse digital bibliographic resources from public databases and libraries. As previously noted, a significant part of the research of this project will be held at CITIC. The Research Center on Information and Communication Technologies (CITIC) is a Technology Center promoted by the University of A Coruña (UDC), to encourage R&D&i applied ICT and located in the Technological Park of the UDC, Elviña Campus. CITIC is a meeting point between university and company that combines R&D departments of companies with university researchers, enabling collaboration and knowledge transfer. CITIC and all of its members is certified ISO 9001 Quality Management System and R&D Management System Certification UNE 166002. The units of CITIC are formed by two intelligent buildings (3.200 sq. m.) that are configurable for R&D activities of researchers, companies and employees. Among other resources, CITIC includes a Data Center with updated equipment and heterogeneous both hardware and software on which tests are performed, pilots, demonstrators and pre-commercial deployments.

4.2. Metodología. Detalle la metodología propuesta de acuerdo con los objetivos del apartado 3.

- Deberá indicarse la viabilidad metodológica de las tareas y reseñar los hitos o entregables previstos. Si fuera necesario, se incluirá una evaluación crítica de las posibles dificultades de un objetivo específico y un plan de contingencia para resolverlas.

  El personal implicado en cada una de las tareas deberá especificarse en el cronograma.

- Si solicita ayuda para la contratación de personal, justifique claramente su necesidad y las tareas que vaya a desarrollar.

Máximo 24 000 caracteres

GENERAL METHODOLOGY: The software process is defined as a framework for the tasks involved in the construction of high quality software. The software process brings the basis for the control of management of the software projects, and it establishes the context in which the technical models are applied, working products are generated, fundamentals are established, quality is garanteed, and changes are appropiately accomplished. To solve the problems which come up in a working environment, it is necessary to incorporate a process model or software engineering paradigm. With regard to the research objective of this project the evolutionary model has been chosen. The evolutionary model is based on the idea of developing of a first initial implementation, expose it to validation results, and refine it through different versions until an adequate system according to validation and established requirements is obtained. Choice of evolutionary model is justified in the nature of the project under consideration aimed at the development of a model of intelligent behavior and with a clear research orientation. In this manner since expert knowledge is of heuristic nature it is not possible to establish a detailed specification for the software aimed at its emulation. Concretely for the analysis of the PSG for SAHS diagnosis, reasoning processes from the experts involve extraction of relevant information from the signals which is difficult to model. Thus, an evolutionary perspective is considered the most suitable for the development of a system of such characteristics.

One fundamental question that needs to be answered before any development of a system is if the system is of utility. It is very important to set from the beginning what is the problem to solve, who are the potential users of the system, and which is the expected impact of the system in the organization. For this purpose it is necessary to carry out a phase for requirements definition phase and determine the kind of problems to be solved or in which environments are they going to be executed. Requirements specification in software consists in an abstract description of services which the system is expected to provide and the restrictions under which the system is supposed to work.

According to IEEE definition software requirements can be classified in two categories: functional and non-functional. A functional requirement defines a function of a software system or its components. A function is described as a set of inputs, the behavior, and outputs. Functional requirements may be calculations, technical details, data manipulation and processing and other specific functionality that define what a system is supposed to accomplish. Each functional requirement can be described as a set of inputs, a behavior and outputs. In our case, an analysis of the neurophysiological activity should be performed in order to characterize patient's sleep macrostructure. This provides fundamental information to assess the sleep pattern of the patient and evaluate the quality of the sleep. Input to this function involves the set of neurophysiological signals including EEG, EMG and EOG. As an output, the hypnogram of the patient is obtained. Also, EEG arousals constitute one of the main indicators of disrupted sleep. They appearance break up the normal sleep cycle and therefore results in restless sleep. Appearance of microarousals during sleep can be because of a number of circumstances, but in apnea patients are related to the apneic event. Therefore its detection and quantification results are also interesting for the detection of the apneic event. Input to this function includes EEG and EMG signals. As an output, number and localization of arousal events is obtained.

Functional requirements are supported by non-functional requirements, which impose constraints on the design or implementation such as performance requirements, security, reliability or usability. Non-functional requirements are also known as quality requirements. Non-functional requirements should establish restrictions in the product under development, in the developing process itself and also with regard to specific restrictions the product may have. A good definition of nonfunctional requirement is that it is a software requirement that describes not what the software will do, but how it will do it. A typical example of nonfunctional requirements is performance. Non functional requirements sometimes are difficult to be objectively verified and therefore often they are evaluated subjectively. They are often associated with the concept of software usability. In our case, success of the approach depends on several factors. The following non-functional requirements should be considered during the development of the system:

Ease of use. It has to be taken into account that it is about the development of a tool to help the clinician, for which managing of the resulting system should not overpass technical capabilities of the final user.

Performance. One of the main objectives of the software is to reduce the diagnostic time necessary for each patient. In this respect analysis time per recording should be minimized as much as possible and, in any case, it should never be higher than manual analysis time from the part of the clinician.

Natural interaction. System-clinician interaction has to be as much natural as possible, without introducing more complexity to the analysis process of the results of the polysomnographic test.

Tidy presentation of the results. System's results should be presented in a systematic and organized form. In this compact report, the most relevant information is summarized allowing the user at each time to breakdown the different items of interest.

Flexibility of the system. Since physiological signals that constitute the input to the system come from a hardware acquisition device, it would be a desirable requirement that the system was able to operate over data coming from the maximum possible number of recording devices.

Extensibility and modifiability. System's design should be modular so that the different components can be easily exchanged. This requirement is important in a context of research and within an evolutionary life cycle. In this regard incremental design of the system is facilitated as well as the possibility to perform continuous improvement over the analysis algorithms.

PROPOSED ARCHITECTURE: The key to the success of this development methodology lies on the use of techniques allowing modification of the system, thus changes can be incorporated and tested as soon as possible. The above requirement have to be taken into account during the development stage, and will be reflected in the architecture of the system, which is highly modular. In this respect it is feasible the identification and the modification of each one of the tasks the system carries out as well as the incorporation of new ones. Each module is in charge of specific functions within the analysis process. Input to the system is given from a digitalized polysomnographic recording containing raw physiological signals from the patient. Data format used will be EDF which is the de-factor standard for PSG digital recordings. Neurophysiological analysis is organized into seven modules: Three are responsible for cerebral activity characterization, eye movements' detection and muscle tone analysis. This information is then fed to the module in charge of obtaining patient's hypnogram. Other three additional modules deal with the detection of transient events including micro-arousals, sleep spindles and K-complexes. These two last (sleep spindles and K-complexes) are also used for the generation of the hypnogram. The whole analysis process is concurrently assisted by functionality of artifact detection, temporal information correlation and reasoning modules. These are organized as general supporting modules since they do not belong to a specific task but intervene at different time instants supporting remaining modules. Artifact detection and fuzzy reasoning processes also intercede at several stages throughout the analysis cycle. Once the signals have been acquired by the system, analysis of neurophysiological activity follows.

METHODS: Analysis of sleep structure comprises the set of so-called neurophysiological signals that includes electroencephalogram (EEG), electrooculogram (EOG) and electromyogram (EMG). Specifically, in the scope of this project pursues a dual objective: (i) determination of the characteristic events from the sleep microstructure such as EEG micro-arousals, K-Complexes and sleep spindles, and (ii) construction of the sleep map of the patient or hypnogram. The former will help the temporal localization of specific events which, as in the case of EEG arousals, may be useful even for the localization of apneic events. This happens since occurrence of both apneic events and EEG arousals has in many cases a cause-effect relationship (the apneic event triggers an EEG arousal). On the other hand, construction of the hypnogram that –among other things- also depend on the detection of microstructure events such as sleep spindles or K-Complexes, serves as a context for the interpretation of the apneic event with regard to the sleep state of the patient. This allows the scorer to sometimes confirm and sometimes discard –depending on the concrete sleep state- the possible occurrence of the apneic event. Specifically the proposed method works with different sleep stages, directly related with R&K and AASM states. The general approach can be organized in three main sequentially related processing steps.

The first step is in charge of performing parameters extraction in which features over the biological signals in the PSG are obtained. Then, after relevant parameters have been extracted at the first phase, information is fed into the second processing step where a reasoning process occurs obtaining as output, a degree of membership with respect to each considered state of sleep. The whole previous process is accomplished in a second-by-second granularity, thus with higher resolution in comparison to epoch-based procedures. This, together with the properties derived from the use of a fuzzy reasoning schema, allow us obtaining a new representation of the hypnogram in which current evolution of the different sleep states is individually characterized. The following steps should be followed for continuous characterization of the sleep macrostructure:

Parameter extraction: According to input information and standard recommendations for sleep analysis, the method proposed works with five signals: both EEG C3/A2 and C4/A1 central derivations, submental EMG and EOG signals from left (EOGL) and right (EOGR) eye electrodes.

Detection of the eye movements: In the case of the EOG the interest is to characterize the eye movements. In order to achieve such a task, an overlapping moving window is shifted throughout both EOGL and EOGR channels, and computing the amplitude of the corresponding signal interval within the window.

Characterization of muscle tone: In the case of EMG, to distinguish between presence and absence of muscle tone, a similar amplitude-based analysis is performed.

Processing of electroencephalographic activity: Regarding the EEG, the different sleep stages are characterized by the different proportion of characteristic frequencies in the most representative bands. Thus, Short-Time Fourier Transform (STFT) is used to compute spectra on every analysis window of the EEG. Then, within each window we quantify the power of the signal at each frequency band by using a band-pass filter in the corresponding range. The Power Spectral Density (PSD) is calculated by integrating the Fourier Transform of the resulting spectra from the filtered signal. Therefore, four measures of PSD are obtained at each time step through the previous process, one for each kind of wave.

Fuzzy Reasoning Process: The fuzzy analysis is divided into submodules, each one being the responsible to accomplish the analysis regarding to one of the considered sleep stages. Each submodule is implemented in the form of a Fuzzy Inference System (FIS) of type Mamdani. This allows us to fulfill the requirement that knowledge could be accessible and extracted in form of human-like decision rules (fuzzy rules).

Hypnogram generation: The following patterns will be clearly shown after completion of the hypnogram generation:

(a)Stage W. It represents the waking state, ranging from full alertness through early stages of drowsiness. Electrophysiological and psychophysiological markers of drowsiness may be present during stage W and may persist into stage N1. In stage W, the majority of individuals with eyes closed will demonstrate alpha rhythm: trains of sinusoidal 8-13 Hz activity recorded over the occipital region which attenuates with eye opening. The EEG pattern with eyes open consists of low amplitude activity (chiefly beta and alpha frequencies) without the rhythmicity of alpha rhythm. The EOG during wakefulness may demonstrate rapid eye blinks at a frequency of about 0.5-2 Hz. As drowsiness develops, the frequency of blinking slows, and eye blinks may be replaced by slow eye movements, even in the presence of continued alpha rhythm. If the eyes are open, voluntary rapid eye movements or reading eye movements may be seen.

(b)Stage N1. It is the lightest sleep state in which the subject can still perceive the majority of stimuli which happen around. Sleep in stage N1 is not practically restful at all. In subjects who generate alpha rhythm, N1 stage is scored when alpha rhythm is attenuated and replaced by low amplitude, mixed (4-7 Hz) frequency activity for more than 50% of the epoch. Other hallmarks of N1 sleep stage are the presence of vertex sharp waves and slow eye movements. Vertex waves are sharply contoured waves with duration <0.5 seconds maximal over the central region and distinguishable from the background activity. Slow eye movements are characterized by reasonably regular, sinusoidal eye movements with an initial deflection usually lasting >500 msec. During stage N1 the chin EMG is variable but often lower than in stage W.

(c)Stage N2. In this stage a blocking of sensorial inputs at the thalamus level is produced. This blocking entails a disconnection from the environment which facilitates the sleeping process. Sleep in stage N2 is partially recovering which suggest that it is not enough to rest completely. EEG activity during N2 is characterized by low amplitude and mixed frequency with predominance of theta frequency but also delta activity increases with respect to stage N1. However main physiological activity characterizing stage N2 comprises the occurrence of transient sleep spindles events and K-complexes. A sleep spindle is defined as a train of distinct waves with frequency 11-16 Hz (mostly commonly 12-14 Hz) with duration ≥0.5 seconds, usually maximal in amplitude using central derivations. K-complexes are defined as well-delineated negative sharp waves immediately followed by a positive component standing out from the background EEG, with duration ≥0.5 seconds, usually maximal in amplitude when recorded using frontal derivations. EOG usually shows no eye movement activity during stage N2 sleep, but slow eye movements may persists in some subjects. On the other hand, the chin EMG is of variable amplitude, but is normally lower than in stage W or N1.

(d)Stage N3. Sensorial blocking intensifies in this stage in respect to N2 which indicate a deeper sleep. If the subject wakes up in this state he/she will probably experiment confusion and disorientation. Sleep in stage N3 is essential for a restful sleep. In this state EEG activity is characterized by the presence of slow waves with predominance of delta frequency. Slow wave activity comprises waves of frequency 0.5-2 Hz and peak-to-peak amplitude >75 µV, measured over the frontal regions. Normally stage N3 is scored when 20% or more of an epoch consists of slow wave activity, irrespective of age. Sleep spindles may persist in stage N3. Eye movements are not typically seen during stage N3 and they might reflect the EEG pattern (which can also happen in N2). In stage N3, the chin EMG is often lower than in stage N2 and sometimes as low as in stage REM.

(e)Stage REM. It is the phase where we typically dream. Cerebral activity in REM stage is fast, with low amplitude and mixed frequency with predominance of theta activity and possible presence of beta bursts. It resembles activity seen in stage N1. A typical transient pattern of EEG activity is the presence of sawtooth waves. A sawtooth wave is a train of sharply contoured or triangular, often serrated, 2-6 Hz waves maximal in amplitude over the central head regions. In some individuals a greater amount of alpha activity can be seen in stage REM than in stage N1, however alpha frequency in stage REM often is 1-2 Hz slower than during wakefulness. In the EOG rapid eye movements are characteristic of this phase which can be identified as conjugate, irregular, sharply peaked eye movements with an initial deflection usually lasting <500 msec. Transient muscle activity is also usual in the EMG which on the other hand normally reaches its lowest amplitude levels. The transient muscle activity appears as short irregular bursts of EMG activity usually with duration <0.25 seconds superimposed on low EMG tone. This activity is maximal in association with rapid eye movements. It is interesting in the scope of this thesis to comment that because of the absence of muscle tone, the possibility of occurrence of an obstruction of the upper airway tract increases during REM. Thus it is a period of special relevance for the diagnosis of SAHS.

SPECIFIC OBJECTIVES AND RELATED TASKS

(Objective1) Design and implementation of the necessary software for the correct identification of the cerebral activity of a patient subjected to nocturnal PSG.

(Objective2) Design and implementation of the necessary software for the correct classification of the cerebral activity of a patient subjected to nocturnal PSG in sleep phases.

(Objective3) Design and implementation of the necessary software for the construction hypnogram of a patient subjected to nocturnal PSG.

(Objective4) Validation of the developed software.

(Objective5) Usability analysis of the approach.

(Objective6) Definition of the strategy for commercial exploitation of the developed software.

For the achievement of these specific objectives the following tasks have been defined:

Characterisation of the cerebral activity.

Task 1.1. Compilation of information: Elicitation of basic and contextual information. In this task acquisition of new relevant knowledge, both neurologycal and technical, is the goal. Deliverable: Dossier with knowledge and procedures.

Task 1.2. Construction of an interface prototype: Design of a small and simple interface that allow to access to the signals involved in the monitoring process. Deliverable: Prototype interface.

Task 1.3. Module of extraction of parameters: This task consists of 2 parts: In the first one, extraction of the relevant parameters of each signal is the goal, and in the second part implementation of signal processing techniques to characterise the parameters is the goal. Deliverable: A module for parameters extraction and characterization.

Module of reasoning: It is the one who realises the fuzzy reasoning. The goal is the correct identification of the patient sleep phases, namely Awake (F0), Light Sleep (FSL), Deep Sleep (FSP) and REM (FR). This objective involves the following tasks:

Task 2.1. Creation of the module F0: This module uses rules based in the previously elicitated knowledge to quantify the possibility that a patient is awake at a given temporal segment. It includes validation. Deliverable: A set of fuzzy rules F0.

Task 2.2. Creation of the module FSP: This module uses rules based in the previously elicitated knowledge to quantify the possibility that a patient is in Deep Sleep at a given temporal segment. It includes validation. Deliverable: A set of fuzzy rules FSP.

Task 2.3. Creation of the module FSL: This module uses rules based in the previously elicitated knowledge to quantify the possibility that a patient is in Light Sleep at a given temporal segment. It includes validation. Deliverable: A set of fuzzy rules FSL.

Task 2.4. Creation of the module FR: This module uses rules based in the previously elicitated knowledge to quantify the possibility that a patient is in REM at a given temporal segment. It includes validation. Deliverable: A set of fuzzy rules FR.

Hypnogram Construction. Integration of results of the previous Objective on a Fuzzy System and visualization of results is the goal. This objective involves the following tasks:

Task 3.1. Module of identification: It obtains the corresponding final "vector" of the hypnogram. Also, in order to improve the operation of the system and delete the conflictive cases caused by the fuzzy reasoning and inconsistent rules after integration, it is important to create rules of context with which, eventually, modify the final vector. Deliverable: A module for identification of the sleep macrostructure.

Task 3.2. Obtaining the hypnogram: Basically the task will convert the outputs of each module expressed in seconds to the scale of epochs, and will select the solution that better satisfy the restrictions imposed. Results will be presented in a graphical manner. It includes validation and refinement. Deliverable: A program that graphically represents the patient's hypnogram.

Overall System Validation. It involves the validation of the proposed system as a whole. The goal is to achieve a good undertanding of the behaviour and performance of the approach. The following tasks have been defined:

Task 4.1. Design of the Proof of Validation: The validation of the system will be performed by using a standard reference. In our case, the standard reference comes represented by the diagnostic effected by experts, on real signals of anonymous patients, through the encrypted database of Case Western Reserve University, pertaining to the study SHHS.

Task 4.2. Execution of the validation guidelines: It may consist on using quantitative measurements to analyse aggreement, partial aggreement, aggreement due by chance, and/or other techniques such as cluster analysis or Williams proofs. Deliverable: A dossier with the conclusions obtained after the validation phase.

System Usability Analysis. This will be performed according to own methodology, thant has already been published, and frequently cited in the international arena, and also frequently used. Deliverable: A dossier with the conclusions obtained after the usability analysis phase. It includes the following tasks:

Task5.1. Subjective analysis

Task5.2. Heuristic analysis

Task5.3. Empirical analysis

Definition of Strategies for Commercial Exploitation. Our working group is a member of CITIC. CITIC is a meeting point between the university and the company that combines R & D departments of companies in the ICT sector with researchers from the university. As members of CITIC we are certified ISO9001 and UNE166002. In this context, we will follow here the suggestions of several consulting companies (ISIS Innovation, EOSA, VALORA…) for the commercial feasibility of the product developed. Tasks and deliverables may include, among others…

Task6.1. Preparation of a catalogue

Task6.2. Construction of a Website

Task6.3. Participation in platforms, forums, and technological fairs.

This project involves considerable effort in Software Engineering, including Programming, that justifies the incorporation by contract of a new member, engineer in informatics for engineering tasks 1.2-1.3-3.1-3.2-4.1-5.1-5.2 and for programming tasks during the project in all tasks.

4.3.1. Cronograma. Para cada objetivo deben indicarse: el investigador responsable del mismo, los participantes involucrados, el período de ejecución (expresado en trimestres) y los hitos y entregables esperados con indicación del trimestre previsto (Tx) para su consecución.

Máximo 24 000 caracteres

Ejemplo:

O1: Breve descripción del objetivo 1
Responsable: Nombre y apellidos
Participantes: Nombre y apellidos P1; Nombre y apellidos P2; Nombre y apellidos P3; Nombre y apellidos P4; Nombre y apellidos Pn
Periodo de ejecución (en trimestres); p. ej., T1 – T2
H1 – Breve descripción del hito 1 y trimestre previsto, p. ej., T1
H2 – Breve descripción del hito 2 y trimestre previsto, p. ej., T2
Hn – Breve descripción del hito n …
E1 – Breve descripción del entregable 1 y trimestre previsto, p. ej., T2
En – Breve descripción del entregable n…

O1. Design and implementation of the necessary software for the correct identification of the cerebral activity of a patient subjected to nocturnal PSG.

Responsible: Vicente Moret Bonillo

Participant 1: Bob Kemp

Participant 2: Diego Alvarez Estévez

Participant 3: Angel Fernández Leal

Participant 4: Elena Hernández Pereira

Participant 5: Jan Casper DeMunck

Participant 6: Contracted Researcher

Execution Time: T1 - T3

H11.Compilation of information: Elicitation of basic and contextual information. In this task acquisition of new relevant knowledge, both neurologycal and technical, is the goal. T1

H12.Construction of an interface prototype: Design of a small and simple interface that allow to access to the signals involved in the monitoring process. T2

H13.Module of extraction of parameters: This task consists of 2 parts: In the first one, extraction of the relevant parameters of each signal is the goal, and in the second part implementation of signal processing techniques to characterise the parameters is the goal. T3

E11. Dossier with knowledge and procedures. T1

E12. Prototype interface. T2

E13. A module for parameters extraction and characterization. T3

O2. Design and implementation of the necessary software for the correct classification of the cerebral activity of a patient subjected to nocturnal PSG in sleep phases.

Responsible: Vicente Moret Bonillo

Participant 1: Jose C. Principe

Participant 2: Diego Alvarez Estévez

Participant 3: Angel Fernández Leal

Participant 4: Eduardo Mosqueira Rey

Participant 5: Elena Hernández Pereira

Participant 6: Jan Casper DeMunck

Participant 7: Contracted Researcher

Execution Time: T3 - T8

H21. Creation of the module F0: This module uses rules based in the previously elicitated knowledge to quantify the possibility that a patient is awake at a given temporal segment. It includes validation. T4

H22. Creation of the module FSP: This module uses rules based in the previously elicitated knowledge to quantify the possibility that a patient is in Deep Sleep at a given temporal segment. It includes validation. T5

H23. Creation of the module FSL: This module uses rules based in the previously elicitated knowledge to quantify the possibility that a patient is in Light Sleep at a given temporal segment. It includes validation. T6

H24. Creation of the module FR: This module uses rules based in the previously elicitated knowledge to quantify the possibility that a patient is in REM at a given temporal segment. It includes validation. T7

E21. A set of fuzzy rules F0. T5

E22. A set of fuzzy rules FSP. T6

E23. A set of fuzzy rules FSL. T7

E24. A set of fuzzy rules FR. T8

O3. Design and implementation of the necessary software for the documented construction of the hypnogram of a patient subjected to nocturnal PSG.

Responsible: Vicente Moret Bonillo

Participant 1: Peter Kerhof

Participant 2: Diego Alvarez Estévez

Participant 3: Elena Hernández Pereira

Participant 4: Mariano Cabrero Canosa

Participant 5: Angel Fernández Leal

Participant 6: Jan Casper DeMunck

Participant 7: Contracted Researcher

Execution Time: T7 - T10

H31. Module of identification: It obtains the corresponding final "vector" of the hypnogram. Also, in order to improve the operation of the system and delete the conflictive cases caused by the fuzzy reasoning and inconsistent rules after integration, it is important to create rules of context with which, eventually, modify the final vector. T8

H32. Obtaining the hypnogram: Basically the task will convert the outputs of each module expressed in seconds to the scale of epochs, and will select the solution that better satisfy the restrictions imposed. Results will be presented in a graphical manner. It includes validation and refinement. T9

E31. A module for identification of the sleep macrostructure. T9

E32. A program that graphically represents the patient's hypnogram. T10

O4. Validation of the developed software. It involves the validation of the proposed system as a whole. The goal is to achieve a good undertanding of the behaviour and performance of the approach.

Responsible: Vicente Moret Bonillo

Participant 1: Eduardo Mosqueira Rey

Participant 2: David Alonso Ríos

Participant 3: Angel Fernández Leal

Participant 4: Diego Alvarez Estévez

Participant 5: Jan Casper DeMunck

Participant 6: Contracted Researcher

Execution Time: T9 - T11

H41. Design of the Proof of Validation: The validation of the system will be performed by using a standard reference. In our case, the standard reference comes represented by the diagnostic effected by experts, on real signals of anonymous patients, through the encrypted database of Case Western Reserve University. T10

H42. Execution of the validation guidelines: It may consist on using quantitative measurements to analyse aggreement, partial aggreement, aggreement due by chance, and/or other techniques such as cluster analysis or Williams proofs. T11

E41. A dossier with the conclusions obtained after the validation phase. T11

O5. Systematic Analysis of the Usability of the system developed. This will be performed according to own methodology, thant has already been published, and frequently cited in the international arena.

Responsible: Vicente Moret Bonillo

Participant 1: Eduardo Mosqueira Rey

Participant 2: David Alonso Ríos

Participant 3: Diego Alvarez Estévez

Participant 4: Bob Kemp

Participant 5: Peter Kerkhof

Participant 6: Contracted Researcher

Execution Time: T10 - T11

H51. Subjective analysis. It implies the use of techniques to obtain information of the users on operative prototypes of the developing product by, for example, direct observation, specific stress tests or control groups. T10

H52. Heuristic analysis. It consists on the application of questionnaires, developed by experts, to analyse the interfaces of the modules, evaluate the architecture and determine strong and weak points from the perspective of the user. T10

H53. Empirical analysis. Definition and application of specific procedures for obtaining objective data about how the users use the system. T11

E51. A dossier with conclusions obtained from the usability analysis phase and eventual improvement procedures. T11

O6. Definition of a strategy for commercial exploitation of the product developed. We will follow here the suggestions of several consulting companies (ISIS Innovation, EOSA, VALORA…) for the commercial feasibility of the product developed.

Responsible: Vicente Moret Bonillo

Participant 1: Mariano Cabrero Canosa

Participant 2: Elena Hernández Pereira

Participant 3: Eduardo Mosqueira Rey

Participant 4: Angel Fernández Leal

Participant 5: Contracted Researcher

Execution Time: T11 - T12

H61. Preparation of a catalogue with the main characteristics of the developed software. T11

H62. Construction of a Website following usability criteria. T11

H63. Participation in platforms, forums, and technological fairs. T12

E61. Dossier and portfolio with marketing material. T12

4.3.2. Cronograma (gráfico). En el cronograma, marque la duración del OBJETIVO (X) y señale con H1...Hx los HITOS, y con E1…Ex los ENTREGABLES, en su caso, de cada objetivo

	Año 1 (trimestres)				**Año 2 (trimestres)**			
Objetivo	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1 (p. ej.)	X	X	H1; H2	E1		H1; H2	E1	
2 (p. ej.)			X	X	H1	H2; E1	E2	H3

AÑOS 1 y 2

	Año 1 (trimestres)				**Año 2 (trimestres)**			
Objetivo	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	X	X	X					
1	H11, E11	H12, E12	H13, E13					
2			X	X	X	X	X	X
2				H21	H22, E21	H23, E22	H24, E23	E24
3							X	X
3								H31

Convocatoria de ayudas a Proyectos de I+D
«EXCELENCIA»
SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO
2013

MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS INDIVIDUALES (TIPO A o B)

AÑOS 3 y 4

	Año 3 (trimestres)				Año 4 (trimestres)			
Objetivo	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
3	X	X						
3	H32, E31	E32						
4	X	X	X					
4		H41	H42, E41					
5		X	X					
5		H51, H52	H53, E51					
6			X	X				
6			H61, H62	H63, E61				

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5. IMPACTO ESPERADO DE LOS RESULTADOS

Describa brevemente el **impacto** científico-técnico, internacional, social o económico que se espera de los resultados del proyecto.

El impacto esperado de los resultados debe completarse también en la aplicación de la solicitud. Su contenido podrá ser publicado a efectos de difusión si el proyecto resultara financiado en esta convocatoria[1].

Máximo 3500 caracteres

The development of this project involves the definition and application of signal analysis techniques and artificial intelligence procedures that pretend the construction of the hypnogram and the detection of transitory events related with the occurrence of apneic episodes. The method proposed for the evaluation of the macrostructure of the sleep comprises three main tasks. In the first place extraction of pertinent characteristics, what includes to analyse the EEG (frequencies), the EOG (ocular movements), characterisation of the EMG, and detection of transitory events like spindles and K-complexes. The set of detected characteristics is carried to a stage of reasoning organised in four fuzzy modules, each one of which is related with a different sleep phase. The continuous evolution of the corresponding sleep phase is represented by means of diffuse labels. In the method proposed, -continuous- means second-to-second. Of course, while we are processing digital signals it never will be possible to achieve a real continuous evolution, but on the other hand, we can approximate asyntotically to said evolution. The big advantage of the continuous representation is that it solves the limitations of the procedures based in -epochs-, used in methodologies like AASM and R&K. On the other hand it is also an aim to keep as much as possible the interpretability of the system. In this regard, the fuzzy approximation allows us implement medical knowledge in as fuzzy rules, near to the human language, what facilitates understanding of the process and allows explanatory capacities. These rules can be consulted, interpreted and finally edited by the final user. Finally, a third step consists in a series of postprocessing techniques that make it possible to go back on the approximation based in epochs. An important reason to keep said representation is that, according to current standards, the clinician are familiar to this temporary scale. Of this way, the clinician can keep the epoch and, simultaneously having accurate information intra-epoch. In this context, the existent products in the market present evident lacks in comparison with the proposal of this project. Besides the fault of identification of sleep states of the patient limits considerably the utility of the commercial monitors. Finally, the quality that expect to achieve in the structures of explanation, interpretation, and justification of results, definitely will result in the improvement of the training of the resident doctors, since it could constitute an excellent tool of education for future specialists. Like summary of impact, the potential customers of the system object of this project are, amongst other, the sleep units of public and private hospitals, to facilitate the diagnostic and treatment of the people with sleep problems. It is a fact that exists an increasing demand in the market of this type of products. We pretend a product software with vocation to be commercialised. By this reason, and to facilitate his commercialisation, we will study the possibility to arrive to agreements of collaboration with skilled companies in computer solutions for hospitals and clinical, that could commission of the tasks of installation of the software, maintenance, training and support to the users. This approach applies also to the international field, as it is shown it the interest and collaboration in the project of groups from United States and of The Netherlands.

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[1] *Si el proyecto resultara financiado en esta convocatoria, el órgano concedente podrá solicitar las conclusiones y los resultados del mismo, que podrán ser publicados a efectos de difusión.*

6. DIFUSIÓN Y TRANSFERENCIA DE LOS RESULTADOS

6.1. PLAN DE DIFUSIÓN.

Máximo 4000 caracteres

A community research partnership is ideally part of a larger collaboration that includes the interests of each partner and spans a wide range of activities. Often a neglected afterthought in busy research schedules, the dissemination of key findings upon project completion is a crucial step in community-based research. In fact, we believe that researchers have an ethical obligation to ensure that research findings are disseminated to research participants, as well as other individuals and institutions in the communities in which we work.

In creating a dissemination plan, researchers should consider several key questions:

Goal: What are the goals and objectives of the dissemination effort? What impact do you hope to have?

Audience: Who is affected most by this research? Who would be interested in learning about the study findings? Is this of interest to a broader community?

Medium: What is the most effective way to reach each audience? What resources does each group typically access?

Execution: When should each aspect of the dissemination plan occur (e.g. at which points during the study and afterwards)? Who will be responsible for dissemination activities?

Key Characteristics of an appropriate dissemination of scientific results are: 1. Orient toward the needs of the audience, using appropriate language and information levels, 2. Include various dissemination methods: written text including illustrations, graphs and figures; electronic and web-based tools; and oral presentations at community meetings and scientific conferences, and 3. Leverage existing resources, relationships, and networks fully.

In this context we can identify several targets for which we have defined appropriate ways for dissemination of results: Group A: Computer Scientists interested in innovative techniques of Artificial Intelligence and Software Development. Group B: Biomedical Engineers and Medical Informaticians. Group C: Social Audience.

For Group A:

JCR Journals such as IEEE TRANSACTIONS ON FUZZY SYSTEMS, IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, KNOWLEDGE-BASED SYSTEMS, DECISION SUPPORT SYSTEMS, IEEE INTELLIGENT SYSTEMS, EXPERT SYSTEMS WITH APPLICATIONS.

Open Access Journals: Journal of Artificial Intelligence Research, INFOCOMP Journal of Computer Science, Journal of Machine Learning Research

International Conferences: AAAI Conference on Artificial Intelligence, IJCAI - International Joint Conference on Artificial Intelligence, ECAI - European Conference on Artificial Intelligence, ACM Conference on Human Factors in Computing Systems.

For Group B:

JCR Journals: IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, MEDICAL & BIOLOGICAL ENGINEERING & COMPUTING, COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE, ARTIFICIAL INTELLIGENCE IN MEDICINE, IEEE ENGINEERING IN MEDICINE AND BIOLOGY MAGAZINE.

Open Access Journals: The Open Biomedical Engineering Journal, BioMedical Engineering OnLine, Journal of Biomedical Engineering and Computational Biology, ISRN Biomedical Engineering — An Open Access Journal.

International Conferences: BioMED - Biomedical Engineering, MedInfo - World Congress on Medical and Health Informatics, BMEI - International Conference on BioMedical Engineering and Informatics, MIE - Medical Informatics Europe, BIOSTEC - International Joint Conference on Biomedical Engineering Systems and Technologies.

For Group C: Media coverage can be an easy way to get results out to as many people as possible. Local and national newspapers, television and radio outlets. We have very good experiences in such a field with other prior projects of great social impact.

6.2. PLAN DE TRANSFERENCIA Y EXPLOTACIÓN, en su caso, de los resultados del proyecto, incluyendo aquellas entidades interesadas en los resultados del proyecto, concretando su participación y/o aportaciones al desarrollo del mismo.

Máximo 4000 caracteres

The process of transfer of knowledge and technology results indispensable in two aspects; internal and external transfer. We will use the facilities offered by CITIC, that realise different activities to boost the technological transfer. The purpose is to facilitate to the companies the access to the results of the groups of investigation. From a perspective of transfer to the productive sector, will follow the councils of the of commercial plan structuring elaborated by EOSA for the team applicant of this project. Questions to be answered are:

(1) How give to know the solutions offered by this research, and (2) The commercialisation of the majority of the developments of software requires of a complete service of installation, maintenance, training and support to users, that would have to be realised by qualified technical personnel.

A possible solution would be to reach agreements of collaboration with computer companies, that could offer these services to facilitate commercialisation. Possible actions are described as a set of performances.

Performance 1: Preparation of a complete catalogue of solutions, that would be accompanied of some another informative material of support (diptyches, technical description of the developed product)

Performance 2: Construction of a Website with a clear orientation to the companies.

Performance 3: Promotion of the Website of in Internet, treating to achieve a good positioning associated to the area of application.

Performance 4: Direct visit to some companies that could be potential customers.

Performance 5: Active participation of the research team in Sectorial Technological Platforms.

Performance 6: Establishment of contacts with Technological Centres that they could be interested in thi line of investigation.

Performance 7: Realise contacts with some companies of software, of consulting and of engineering, in order arrive to an agreement of collaboration so that these could assume the services of installation, maintenance, training and support to the users of the software developed by the group. Likewise, these companies also could collaborate in the commercialisation of the product, incorporating it inside his own catalogue.

Performance 8: Treat to reach agreements with manufacturers of teams of medical monitoring to integrate the developed system.

We consider that in this way it could facilitate the communication with the companies and the put in value of the services and products that could offer them this group of investigation.

According to this strategy, we established a professional relation with IMAXDI. IMAXDI Is a biomedical engineering company biomédica in the development of medical devices laptops of last generation and mobile applications for the improvement of the health. From 2011 IMAXDI keeps a cordial and narrow relation with the Laboratory of R & D in Artificial Intelligence (LIDIA) of the University of A Coruña (UDC). The Division IMAXI R & D knows and follows the trajectory of the Group of Biomedical Applications of the Artificial Intelligence, directed by the Dr. Vicente Moret Bonillo. of the quoted laboratory of the UDC, and has kept conversations for the eventual commercialisation of any of his products and developments, specifically in the fields of the intelligent monitoring and of the analysis of usability of biomedical systems. IMAXDI will act as an active observer of the developments achieved in this project.

7. FINANCIACIÓN PÚBLICA Y PRIVADA (PROYECTOS Y CONTRATOS DE I+D+i) DEL EQUIPO DE INVESTIGACIÓN

Indique únicamente la financiación en los últimos 5 años (2009-2013), ya sea de ámbito autonómico, nacional o internacional. Incluya también las solicitudes pendientes de resolución.

Debe indicar: referencia, título, investigador principal, entidad financiadora, duración y cuantía de la subvención, además de las siguientes claves: 0 = es el mismo tema; 1 = está muy relacionado; 2 = está algo relacionado; 3 = sin relación; C o una S según se trate de una concesión o de una solicitud.

Máximo 20 proyectos o contratos.

Máximo 12 000 caracteres

Ejemplo:

1. Referencia XXX2009-nnnnn. "Título", "Investigador principal", MICINN, 01/2010-12/2012. xx.xxx €. 1-C
2. Referencia XXX2012-nnnnn. "Título", "Investigador principal", MINECO, 01/2013-12/2015. xxx.xxx €. 3-C
3. FP7-NMP-20xx-SMALL-x. "Título", "Investigador principal", UE, 01/2013-12/2015. xxx.xxx €. 2-C
4. FP7-PEOPLE-2012-ITN. Título", "Investigador principal", UE, 01/2013-12/2015. xxx.xxx €. 1-S

…

20.

1.Referencia 09SIN003CT.

Monitor Inteligente de Fases de Sueño.

IP: Vicente Moret Bonillo.

Xunta de Galicia, 2009-2012.

75.514,75 €. 0-C

2.Referencia 08SIN010CT.

Desarrollo de metodologías, técnicas y herramientas de análisis de usabilidad y accesibilidad de sitios y aplicaciones web.

IP: Eduardo Mosqueira Rey.

Xunta de Galicia, 2008-2011.

82.800,00 €. 1-C

3.Referencia CN20112/211.

Ayudas para la consolidación y la estructuración de unidades de investigación competitivas del Sistema Universitario de Galicia (modalidad Agrupaciones Estratégicas).

IP: Ricardo Cao Abad.

Xunta de Galicia, 2012-2013.

500.000,00 €. 1-C

4.Referencia CN2008/060.

Programa de consolidación e estruturación de unidades de investigación competitivas. Modalidade de agrupacións estratéxicas.

IP: Víctor Gulías Fernández.

Xunta de Galicia, 2008-2010.

625.000,00 €. 1-C

5.Referencia CN2011/007.

Programa de consolidación e estruturación de unidades de investigación competitivas. Modalidade de grupos de referencia competitiva.

IP: Amparo Alonso Betanzos.

Xunta de Galicia, 2011-2013.

168.000,00 €. 1-C

6.Referencia Contrato 092/08.

Actuacións de mellora de rendemento no motor de debuxo dunha ferramenta de planificación de redes eléctricas e estudo de aplicacións técnicas de análise de series temporais de sistemas de control e adquisición de datos (SCADA).

IP: Elena Hernández Pereira.

Unión Fenosa, 2009.

46.400,00 €. 3-C

7.Referencia Contrato INV02410.

Desarrollo de rutinas gráficas de visualización de alto rendimiento para una herramienta de gestión de topologías de redes eléctricas de gran tamaño.

IP: Elena Hernández Pereira.

Gas Natural-Unión Fenosa. 2010.

46.400,00 €. 3-C

8. Referencia Contrato INV02411 Renovación.

Desarrollo de rutinas gráficas de visualización de alto rendimiento para una herramienta de gestión de topologías de redes eléctricas de gran tamaño.

IP: Elena Hernández Pereira.

Gas Natural-Unión Fenosa. 2011.

46.400,00 €. 3-C

9. Referencia Contrato INV02412 Renovación.

Desarrollo de rutinas gráficas de visualización de alto rendimiento para una herramienta de gestión de topologías de redes eléctricas de gran tamaño.

IP: Elena Hernández Pereira.

Gas Natural-Unión Fenosa. 2012.

46.400,00 €. 3-C

10. Referencia Contrato INV02413 Renovación.

Desarrollo de rutinas gráficas de visualización de alto rendimiento para una herramienta de gestión de topologías de redes eléctricas de gran tamaño.

IP: Elena Hernández Pereira.

Gas Natural-Unión Fenosa. 2013.

46.400,00 €. 3-C

11. Referencia Grant Agreement 228357-7Th Framework Programme.

Galileo Speed Warning (GSW).

IP: Jonathan Guard.

European GNSS Supervisory Autority -GSA-, 2009-2010.

299.392,00 €. 2-C

12.Referencia PGIDIT06SIN038E.

PROSAICO: Un sistema de ayuda a la decisión para la prescripción y supervisión personalizada de actividad física orientada a la mejora de la salud y del rendimiento deportivo.

IP: Eduardo Mosqueira Rey.

Xunta de Galicia y SIDECU Gestión. 2006-2009.

62.290,00 €. 1-C

13.Referencia 09SIN027E.

PROSAICO-SAUDE: Desenvolvemento dun sistema de axuda a decision para a prescripcion de exercicio fisico en suxeitos non saudables.

IP: Eduardo Mosqueira Rey.

Xunta de Galicia y SIDECU Gestión. 2009-2012.

40.812,50 €. 1-C

14.Referencia Contrato.

Digital Human Behaviour : Tecnologías inteligentes para el análisis del comportamiento de los usuarios en el acceso y consumo de contenidos digitales en multiplataformas.

IP : Amparo Alonso Betanzos.

PRISA DIGITAL. 2012-2013.

88.500,00 €. 2-C

8. RELACIÓN DE LAS PERSONAS QUE COMPONEN EL EQUIPO DE TRABAJO

Relacione las personas del equipo de trabajo que participarán en la ejecución del proyecto de investigación (de acuerdo con el artículo 18.9 de la convocatoria). Recuerde que el currículum de los doctores aquí incluidos deberá aportarse en la aplicación de solicitud del proyecto.

Máximo 8000 caracteres

***Indique NOMBRE Y APELLIDOS** y las siguientes claves según proceda:*

TITULACIÓN: Doctor (D); Licenciado o ingeniero (L); Graduado (G); Máster (M); Formación profesional (FP); Otros (O)

TIPO DE CONTRATO: En formación (F); Contratado (C); Técnico (PT); Entidad extranjera (EE); Otros (OC)

DURACIÓN DEL CONTRATO: Indefinido (I); Temporal (T)

1. Nombre y apellidos. G-F-T
2. Nombre y apellidos. FP-PT-I
3. Nombre y apellidos. EE

1. Jose C. Principe. D-EE
2. Peter Kerkhof. D-EE
3. Bob Kemp. D-EE
4. Diego Alvarez. D-EE
5. Jan Casper DeMunck. D-EE

9. CAPACIDAD FORMATIVA DEL EQUIPO SOLICITANTE

Complete únicamente en caso de que se solicite la inclusión del proyecto en la convocatoria de "*Contratos predoctorales para la formación de doctores*"[2].

Especifique:

- plan de formación previsto en el contexto del proyecto solicitado;
- relación de tesis realizadas o en curso con indicación del nombre del doctorando, el título de tesis y la fecha de obtención del grado de doctor o de la fecha prevista de lectura de tesis (últimos 10 años).

Máximo 8000 caracteres

From an educational point of view our group is engaged in the consecution of a high level of knowledge among our students, thus participating actively in the doctoral program of the Computer Science Department at UDC, as well as in other formative actions like seminairs (Last one on september-november, 15 hours "Introduction to Quantum Computing", Vicente Moret) The aim of the Doctorate in Computation is the training of new doctors in the area of Advanced Computation, that involves giving high level skills for preparation of the thesis doctoral and defence in front of a court of experts. We have to provide a training advanced in methodology of the investigation and the tasks related: systematic acquisition of knowledge of the state of the art, development of the scientific method, approach of hypothesis, evaluation of results, preparation of publications and presentation of work of investigation. Specific points are:

Systematic understanding of a field of study and command of the skills and methods of investigation related with said field.

Capacity to conceive, design or create, put in practice and adopt appropriate and efficient capabilities for investigation or creation.

Capacity to contribute to the extension of the borders of the knowledge through of original investigation.

Capacity to realise a critical analysis and of evaluation and synthesis of new and complex ideas.

Capacity of communication with the academic and scientific community and with the society in general about his fields of knowledge in the ways and languages commonly used in the international scientific community;

Capacity to boost, in academic and professional contexts, the scientific advance, technological, social, artistic or cultural inside a society based in the knowledge.

In the particular case of our research team, in the last five years we have been responsible of the following courses, directly related with the purpose of this project::

1.Intelligent Monitoring Systems

2.Validation and Usability of Computer Systems

3.Physical Models in Advanced Computer Science

4. Computational Logics

---

[2] *La inclusión en la convocatoria de "Contratos predoctorales para la formación de doctores" solo será posible en un número limitado de los proyectos aprobados*

5. Machine Learning

6. Multi-Agent Systems

Directly related with the topic of this research, the following thesis have been directed by the IP of this project:

Director VICENTE MORET BONILLO

Título INTEGRACIÓN DE DATOS, INFORMACIÓN Y CONOCIMIENTO EN UNA ARQUITECTURA PARA LA MONITORIZACIÓN INTELIGENTE DEL PACIENTE CRÍTICO

Fecha de defensa: NOVIEMBRE DE 1998

Nombre del doctorando MARIANO JAVIER CABRERO CANOSA

Institución UNIVERSIDAD DE A CORUÑA

Calificación SOBRESALIENTE CUM LAUDE

Director VICENTE MORET BONILLO

Título SHIVA: UN SISTEMA HEURÍSTICO E INTEGRADO PARA LA VALIDACIÓN DE SISTEMAS INTELIGENTES

Fecha de defensa: NOVIEMBRE DE 1998

Nombre del doctorando EDUARDO MOSQUEIRA REY

Institución UNIVERSIDAD DE A CORUÑA

Calificación SOBRESALIENTE CUM LAUDE

Directores VICENTE MORET BONILLO Y FRANCISCO DEL POZO GUERRERO

Título ALARMAS INTELIGENTES EN UNIDADES DE CUIDADOS INTENSIVOS BASADAS EN REDES NEURONALES

Fecha de defensa: NOVIEMBRE DE 1999

Nombre del doctorando JORGE DÍAZ FERNÁNDEZ

Institución UNIVERSIDAD POLITÉCNICA DE MADRID

Calificación SOBRESALIENTE CUM LAUDE

Director VICENTE MORET BONILLO

Título TÉCNICAS DE INTELIGENCIA ARTIFICIAL Y DE INGENIERÍA DEL SOFTWARE PARA UN SISTEMA INTELIGENTE DE MONITORIZACIÓN DE APNEAS EN SUEÑO

Fecha de defensa: OCTUBRE DE 2000

Nombre del doctorando ELENA MARÍA HERNÁNDEZ PEREIRA

Institución UNIVERSIDAD DE A CORUÑA

Calificación SOBRESALIENTE CUM LAUDE

Director VICENTE MORET BONILLO

Título UN MARCO DE TRABAJO PARA LA REPRESENTACIÓN DE CONOCIMIENTO TEMPORAL

Fecha de defensa: OCTUBRE DE 2006

Nombre del doctorando ANGEL FERNÁNDEZ LEAL

Institución UNIVERSIDAD DE A CORUÑA

Calificación SOBRESALIENTE CUM LAUDE

Directores MANUEL A. GIRÁLDEZ GARCÍA y VICENTE MORET BONILLO

Título PAP: UN PROGRAMA INFORMÁTICO PARA AVALIAçAO, PRESCRIçAO, PERIODIZAçAO E CONTROLE DE EXERCÍCIOS FÍSICOS SAUDÁVEIS

Fecha de defensa: JULIO DE 2009

Nombre del doctorando LUIZ FERNANDO PINHEIRO MACHADO AQUINI

Institución UNIVERSIDAD DE A CORUÑA

Calificación SOBRESALIENTE CUM LAUDE

Director VICENTE MORET BONILLO

Título DIAGNÓSTICO INTELIGENTE DEL SÍNDROME DE APNEAS-HIPOPNEAS DEL SUEÑO UNA APROXIMACIÓN INTEGRAL MEDIANTE UN SISTEMA INTELIGENTE DE APOYO A LA DECISIÓN CLÍNICA

Fecha de defensa: OCTUBRE DE 2012

Nombre del doctorando DIEGO ALVAREZ ESTEVEZ

Institución UNIVERSIDAD DE A CORUÑA

Calificación SOBRESALIENTE CUM LAUDE

Other thesis are:

TÍTULO: PROSAICO: Un sistema inteligente para la prescripción y supervisión personalizada de actividad física orientada a la mejora de la salud y del rendimiento deportivo

DOCTORANDO: Diego Antonio Prado Gesto

UNIVERSIDAD:Coruña

FACULTAD/ESCUELA: Facultad de Informática
AÑO: Expected July-2014
CALIFICACIÓN: Under Development

TÍTULO: Desarrollo de taxonomías de usabilidad y de contexto de uso, integración en las técnicas de estudio de la usabilidad y aplicación a casos reales
DOCTORANDO: David Alonso Ríos
UNIVERSIDAD:ACoruña
FACULTAD/ESCUELA: Facultad de Informática
AÑO: Expected March-2014
CALIFICACIÓN: Under Development

TÍTULO: Agentes Inteligentes Evolutivos y su Aplicación a la Usabilidad de Sitios Web
DOCTORANDO: María Belén Baldonedo del Río
UNIVERSIDAD:A Coruña
FACULTAD/ESCUELA: Facultad de Informática
AÑO: 2011
CALIFICACIÓN: Sobresaliente (cum laude)

Título: Tecnología RFID en el ámbito sanitario: desarrollo de una solución software para trazabilidad de pacientes y minimización de eventos adversos en un servicio de urgencias.
Doctorando: Marta Martínez Pérez
Universidad: Universidade da Coruña
Facultad / Escuela: Facultade de Informática
Fecha: 2012
Calificación: Sobresaliente cum laude.

10. IMPLICACIONES ÉTICAS Y/O DE BIOSEGURIDAD DE LA INVESTIGACIÓN PROPUESTA

Si en la aplicación electrónica de solicitud ha contestado **afirmativamente** en alguno de los aspectos relacionados con implicaciones éticas o de bioseguridad allí recogidos, explique los aspectos éticos referidos a la investigación que se propone, las consideraciones, procedimientos o protocolos a aplicar en cumplimiento de la normativa vigente, así como las instalaciones y las preceptivas autorizaciones de las que dispone para la ejecución del proyecto.

Máximo 8000 caracteres

Convocatoria de ayudas a Proyectos de I+D
«EXCELENCIA»
SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO
2013

MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS INDIVIDUALES (TIPO A o B)

ANEXO I

Incluya las fórmulas, reacciones químicas, etc., que por el tipo de letra del texto del formulario no hayan podido ser insertadas en el mismo. El número de ecuación debe coincidir con su llamada en el texto.

Máximo 2 páginas

Respete la extensión máxima indicada. Recuerde que en virtud del artículo 11 de la convocatoria **NO SE ACEPTARÁN NI SERÁN SUBSANABLES MEMORIAS CIENTÍFICO-TÉCNICAS** que no se presenten en este formato.

GOBIERNO DE ESPAÑA · MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Convocatoria de ayudas a Proyectos de I+D
«EXCELENCIA»
SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO
2013

MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS INDIVIDUALES (TIPO A o B)

ANEXO II

Únicamente en caso de que se considere necesario para aclarar ciertos aspectos del proyecto, incorpore las imágenes o figuras (formato TIFF, JPEG o GIF), hasta un máximo de 6, a las que se haya hecho referencia en el texto.

Respete el número máximo de figuras indicado. Recuerde que en virtud del artículo 11 de la convocatoria **NO SE ACEPTARÁN NI SERÁN SUBSANABLES MEMORIAS CIENTÍFICO-TÉCNICAS** que no se presenten en este formato.

imaxdi
WWW.IMAXDI.COM

Ph.D. Javier Álvarez Osuna
Director I+D+i
IMAXDI- Real Innovation
c/ Manuel Núñez, 4-3ª Planta
36203 Vigo

A Quien Pueda Interesar

Como director de I+D+i de la empresa IMAXDI Real Innovation, con sede en Vigo, España, me complace informar de lo siguiente:

1. IMAXDI es una compañía biomédica centrada en el desarrollo de dispositivos médicos portátiles de última generación y aplicaciones móviles para la mejora de la salud.
2. Desde 2011 IMAXDI mantiene una cordial y estrecha relación con el Laboratorio de I+D e Inteligencia Artificial (LIDIA) de la Universidad de A Coruña (UDC)
3. IMAXI I+D+i conoce y sigue la trayectoria del Grupo de Aplicaciones Biomédicas de la Inteligencia Artificial, dirigido por el Dr. Vicente Moret Bonillo) del citado laboratorio de la UDC, y ha mantenido conversaciones para la eventual comercialización de alguno de sus productos y desarrollos, concretamente en los ámbitos de la monitorización inteligente y del análisis de usabilidad de sistemas biomédicos.

A tenor de lo anteriormente expuesto, IMAXDI I+D+i declara estar potencialmente interesada en los resultados derivados del proyecto titulado "INTELLIGENT ANALYSIS OF NEUROPHYSIOLOGICAL SIGNALS AND HYPNOGRAM CONSTRUCTION FOR EVENTS DETECTION AND INTERPRETATIONS IN THE SLEEP APNEA SYNDROME" del cual es Investigador Principal el Dr. Vicente Moret Bonillo, y que será próximamente presentado al *Programa Estatal de Fomento de la Investigación Científica y Técnica de Excelencia, Subprograma Estatal de Generación de Conocimiento, en el marco del Plan Estatal de Investigación Científica y Técnica y de Innovación 2013-2016.*

Vigo, 15 de noviembre de 2013.

Fdo.: Javier Álvarez Osuna, Ph.D.

GOBIERNO DE ESPAÑA

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Convocatoria de ayudas a Proyectos de I+D
«EXCELENCIA»
SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO
2013

MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS INDIVIDUALES (TIPO A o B)

Physics and Medical Technology

De Boelelaan 1118 P.O. Box 7057; ZH 3D20 T: 020 4444714 www.vumc.nl
1081 HZ Amsterdam 1007 MB Amsterdam plm.kerkhof@vumc.nl

VU medisch centrum

Dr. Vicente Moret-Bonillo
Department of Computer Science
Faculty of Informatics,
University of A Coruña,
15071 A Coruña. Spain.

Dear Dr. Moret-Bonillo:

It is my pleasure to collaborate as "Invited Professor" in the research project entitled "INTELLIGENT ANALYSIS OF NEUROPHYSIOLOGICAL SIGNALS AND HYPNOGRAM CONSTRUCTION FOR EVENTS DETECTION AND INTERPRETATIONS IN THE SLEEP APNEA SYNDROME" in which you are the Responsible Researcher, and to be presented to the Spanish Programa Estatal de Fomento de la Investigación Científica y Técnica de Excelencia, Subprograma Estatal de Generación de Conocimiento, en el marco del Plan Estatal de Investigación Científica y Técnica y de Innovación 2013-2016.

I will contribute with my expertise in Biomedical Engineering to complement the work in your laboratory, and I expect to achieve substantial results in this very important area of Sleep Apnea Diagnosis an Interpretations.

Please, let me know if you need a copy of my CV.

Sincerely,

Peter L. M. Kerkhof, B.M., Ph.D.
VU University Medical Center
Amsterdam

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Convocatoria de ayudas a Proyectos de I+D
«EXCELENCIA»
SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO
2013

MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS INDIVIDUALES (TIPO A o B)

UF UNIVERSITY of FLORIDA

College of Engineering
Department of Electrical & Computer Engineering

216 LARSEN HALL
PO Box 116200
Gainesville, FL 32611-6200
352-392-0912
352-392-8671 Fax

November 11, 2013

Dr. Vicente Moret-Bonillo
Department of Computer Science
Faculty of Informatics,
University of A Coruña,
15071 A Coruña
Spain.

Dear Dr. Moret-Bonillo:

It is my pleasure to collaborate as an "Invited Professor" in the research project entitled "INTELLIGENT ANALYSIS OF NEUROPHYSIOLOGICAL SIGNALS AND HYPNOGRAM CONSTRUCTION FOR EVENTS DETECTION AND INTERPRETATION IN THE SLEEP APNEA SYNDROME" in which you are the Responsible Researcher, to be presented to the Spanish Programa Estatal de Fomento de la Investigación Científica y Técnica de Excelencia, Subprograma Estatal de Generación de Conocimiento, en el marco del Plan Estatal de Investigación Científica y Técnica y de Innovación 2013-2016. I will contribute with my expertise to complement the work in your laboratory, and I expect to achieve substantial results in this very important area of Sleep Apneas Diagnosis an Interpretations. Please, let me know if you need a copy of my CV.

Truly Yours,

Jose C. Principe, Ph.D.
Distinguished Professor of Electrical Engineering
BellSouth Professor
University of Florida

The Foundation for The Gator Nation
An Equal Opportunity Institution

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Convocatoria de ayudas a Proyectos de I+D
«EXCELENCIA»
SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO
2013

MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS INDIVIDUALES (TIPO A o B)

MCH
Medisch Centrum Haaglanden

Dr. Vicente Moret-Bonillo
Department of Computer Science
Faculty of Informatics,
University of A Coruña,
15071 A Coruña
Spain.

Dear Dr. Moret-Bonillo:

It is my pleasure to collaborate as "Invited Professor" in the research project entitled "INTELLIGENT ANALYSIS OF NEUROLOGICAL SIGNALS AND HYPNOGRAM CONSTRUCTION FOR EVENTS DETECTION AND INTERPRETATIONS IN THE SLEEP APNEA SYNDROME" in which you are the Responsible Researcher, to be presented to the Spanish *Programa Estatal de Fomento de la Investigación Científica y Técnica de Excelencia, Subprograma Estatal de Generación de Conocimiento, en el marco del Plan Estatal de Investigación Científica y Técnica y de Innovación 2013-2016*. I will try to contribute with my expertise as Neuro-Physicist to complement the work in your laboratory, and I expect to achieve substantive results in this very important area of Sleep Apneas Diagnosis an Interpretations. Please, let me know if you need a copy of my CV.

Truly Yours,

Bob Kemp, PhD.

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Convocatoria de ayudas a Proyectos de I+D
«EXCELENCIA»
SUBPROGRAMA DE GENERACIÓN DE CONOCIMIENTO
2013

MEMORIA CIENTÍFICO-TÉCNICA DE PROYECTOS INDIVIDUALES (TIPO A o B)

MCH
Medisch Centrum Haaglanden

Dr. Vicente Moret-Bonillo
Department of Computer Science
Faculty of Informatics,
University of A Coruña,
15071 A Coruña
Spain.

Dear Dr. Moret-Bonillo:

It is my pleasure to collaborate as "Collaborating professor" in the research
entitled "INTELLIGENT ANALYSIS OF NEUROLOGICAL SIGNALS A
HYPNOGRAM CONSTRUCTION FOR EVENTS DETECTION AND
INTERPRETATIONS IN THE SLEEP APNEA SYNDROME" in which yo
Responsible Researcher, to be presented to the Spanish *Programa Estatal d*
de la Investigación Científica y Técnica de Excelencia, Subprograma Estata
Generación de Conocimiento, en el marco del Plan Estatal de Investigación
Técnica y de Innovación 2013-2016. I will try to contribute with my expertis
area of application of artificial intelligent techniques to the analysis of sleep
diagnosis of sleep disorders. It is worth to mention that my doctoral thesis e
"Diagnosis of the Sleep Apnea-Hypopnea Syndrome: a comprehensive appr
through an intelligent system to support medical decision" was precisely dev
under this area and with Dr. Vicente Moret-Bonillo as my supervisor. Please
CV attached.

Truly Yours,

Diego Alvarez-Estevez, PhD.