Retrieving physiological features in decision support systems*

-A Doctoral Thesis Proposal.-

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1 Project Description

The Artificial Intelligence in Medical Applications (AIM) project at the Department of Computer Science and Electronics (IDE) officially started in january 2002 and is mainly externally funded. A three year grant from Kunskap och Kompetens Stiftelsen (KKS)[1] was granted in mid 2001 for the funding of two doctoral students in Artificial Intelligence (AI). Additional funding was matched by PBM StressMedicine[2] as they would benefit from the research. The department provides additional funding by providing workplaces, supervisors etc. The supervisors are Peter Funk and Björn lisper.

The area of interest for this research is to capture knowledge with AI based methods for the use in decision support systems. The knowledge in this case pertain to a few experts in a special branch of psychophysiological medicine[13] where practitioners and clinicians use physiological measurements to diagnose patients with stress related dysfunctions[11, 17, 18]. The treatment is often based on some sort of biofeedback training[7, 9]. This is our definition of psychophysiology in the remainder of the document. The project is divided into two parts, one per doctoral student. The first part, which is the part this doctoral thesis proposal is based upon, handles physiological parameters, i.e., measurements from patients[4, 7]. They have to be examined for important information, such features clinicians find useful in their diagnosis. The approach for finding these features is to analyse the raw signals, thus signal theory is a essential part of this part of the project. The first part can be used as a stand-alone decision support system or be used as a pre-processor to the second part of the AIM project. Additional help for clinicians is provided by the second part of the project. This part identifies important sequences of pre-classified signals by clustering sequences to known patterns. This gives a more complete analysis of the measurements as it explains the measurements in a more familiar enviroment.

The research has lead to the development of a new classification method for the identification of important features in physiological parameters [16] in medical support systems. The classification method is implemented in a decision support system, HR3Modul[15], for diagnosing respiratory sinus arrhythmia (RSA) [18].

Project members are:

Peter Funk	Main supervisor (AI)	IDE
Bo von Schéele	Main supervisor (medicine)	StressMedicine/Karolinska institutet
Björn Lisper	Supervisor	IDE
Markus Nilsson	Doctoral student	StressMedicine/IDE
Mikael Sollenborn	Doctoral student	StressMedicine/IDE
Johnny Holmberg	Advisor in signal theory	IDE
Erik Olsson	Advisor in medicine	StressMedicine/Uppsala University

[1] KKS is the Swedish Knowledge Foundation, URL http://www.kks.se.
[2] URL http://www.pbmstressmedicine.com

2 Problem Formulation

It is in general difficult to find patterns within biomedical signals, i.e. physiological time series. This also applies to our domain of interest. The RSA domain has also the non-favourable attribute of beeing unkown in some parts. It is not widely known how to identify and compare features in individual breaths, thus makes it difficult to make a general classifier, as the classifier has to incorporate unknown variables. The question is how do we classify these biomedical signals if the domain is not fully understood? And how do we make a system that is autonomous enough for users to add, remove or change the systems memory to find these unknown variables?, preferably without any modifications of the system, or re-validations of the systems memory.

Artificial Intelligence methods often separate the knowledge from the methods themselves [10, 12]. An AI method is often able to change it's knowledge without the need for revising its reasoning method. Hence, the knowledge of the system is not tied to the knowledge of the constructor of the system. We have chosen Case-Based Reasoning (CBR) [1, 8, 19] as our AI method. The CBR paradigm is based on a model of human thinking that originates from psychology, the model is cognitive plausible [6]. CBR is dynamic enough for our purposes as it has the ability of revising parts of the knowledge base, i.e. the memory, without the need for revising the entire memory afterwards. A CBR based knowledge system does also have the benefit of explaining the solution, to for instance clinicians, by showing explicit examples. That increases the probability of acceptance by the users. Our approach to the signal classification is to apply Case-Based retrieval, where the memory is composed of already known and classified signals. Cases are retrieved by a novel matching and retrieval method [14] based on frequency analysis by using wavelets [3, 2].

3 Contributions

The contributions of this thesis are:

- A novel retrieval and weighting method for CBR systems that handles sequences of different samples lengths. The method uses a Daubechies D4 wavelet for the identification and retrieval of features from the samples. The features are matched according to their position in the two dimensional time-frequency map. The matched features are automatically weighted based on their frequency band.
- A decision support system for clinicians specialised in treating physiological dysfunctions with psychophysiological medicine.
- A cardio-pulmonary tool for the identification of heartbeats corresponding to specific breaths.

4 Outline of the Doctoral Thesis

The doctoral thesis will be a collection of six articles. The articles are described in more detail in section 5. Out of these six articles, there are one journal, four full length conference papers, and a paper published at the first workshop in our specific research area, medical CBR. These articles will be introduced by an introductionary "coat". The "coat" introduce the subjects in the thesis, i.e., CBR and psychophysiology, it also presents related work and contributions.

The outline of the thesis will be as follows:

Introductionary coat which will describe the background, motivation, problem description, and contributions of the thesis.

Paper A A longer journal paper that describes a decision support system for clinical use by addressing every step in the process, from raw signals to the help in the diagnosis.

Paper B Paper B contains a thorough analysis of the medical CBR area by presenting a survey of research systems and methodologies. The paper also analyses trends in the community.

Paper C This paper presents a model for constructing a medical system that classifies RSA from physiological signals by using CBR.

Paper D The paper describes a prototype system based on paper C. The prototype system uses both CBR and Rule-Based Reasoning (RBR) for the classification.

Paper E A mostly theoretical paper that describes (and evaluates) a new retrieval method for classification of RSA that eliminates the need for RBR.

Paper F And the final paper describes the implementation of the retrieval method from paper E in to the existing classification system.

5 Papers to be Included in the Doctoral Thesis

Paper A

Markus Nilsson, Peter Funk, Erik M. G. Olsson, Bo von Schéele, Ning Xiong, Mikael Sollenborn
Clinical decision support for diagnosing stress related disorders by applying psychophysiological medical knowledge in a layered knowledge based system
Accepted for publication in Journal of Artificial Intelligence in Medicine (AIM)

The journal paper addresses both physiological and computer science aspects on how to classify physiological signals and how to present that information to clinicians. The classification is divided in to two levels, the first classifies individual breaths and the second identifies sequences within the classified breaths. This approach gives a more extensive decision support than by only presenting classified signals.

Contributing authors:	Markus Nilsson	Main author of paper
		Classification system + signal processing
	Peter Funk	Co-author of paper
		Pattern series identification
	Erik M. G. Olsson	Co-author of paper
		Physiological aspects
	Bo von Schéele	Advisor in psychophysiology
	Ning Xiong	Co-author of paper
		Retrieval performance
	Mikael Sollenborn	Project member

Paper B

Markus Nilsson, Mikael Sollenborn
Advancements and Trends in Medical Case-Based Reasoning: An Overview of Systems and System Development
In Proceedings of the 17th International FLAIRS Conference (FLAIRS'04)
pages 178-183, May 2004, Miami, USA

This paper analyses the area of CBR in medicine and it is a follow up work based on Smith & Gierl's survey in 1998 [5]. The paper addresses the issues outlined by Smith & Gierl and assesses wheter they are solved or have been changed. New issues are also identified as well as research trends within the community. A substantial part of the community helped us in the process by answering questionares etc.

Contributing authors:	Markus Nilsson	Main (joint) author of paper
	Mikael Sollenborn	Main (joint) author of paper

Paper C

Markus Nilsson, Peter Funk, Mikael Sollenborn
Complex Measurement Classification in Medical Applications Using A Case-Based Approach
In Workshop on CBR in the Health Sciences (ICCBR'03)
pages 63-72, June 2003, Trondheim, Norway

This is the first paper in the AIM project, it outlines a pattern classification model based on CBR. RSA is classified by dividing the classification task in to three parts, pre-processing of physiological signals, a signal classifier part and a part where patient specific information revises the classified signals.

Contributing authors:	Markus Nilsson	Main (joint) author of paper Additional ideas of contribution
	Peter Funk	Main (joint) author of paper Main ideas of contribution
	Mikael Sollenborn	Project member

Paper D

Markus Nilsson, Peter Funk
A Case-Based Classification of Respiratory Sinus Arrhythmia
In Proceedings of the European Conference on Case-Based Reasoning (ECCBR'04)
pages 673-685, September 2004, Madrid, Spain

A multi-modal reasoning system is presented in this paper. The system classifies RSA by analysing both the breathing and the heart rate. Heart rate samples corresponding to a breath is classified by CBR and RBR. The rules in the RBR part limit the case library size by looking for explicit features, and CBR matches the remaining cases by weighted euclidian distances in the frequency domain.

Contributing authors:	Markus Nilsson	Author of paper Ideas + prototype system
	Peter Funk	Project supervisor

Paper E

Markus Nilsson
Retrieving short and dynamic biomedical sequences
Accepted for publication at the FLAIRS'05 conference, May 2005, Clearwater Beach, USA

This paper presents a new retrieval method for sample sequences with dynamic lengths. The sequences are transformed to the time-frequency domain by a Daubechies D4 wavelet, and frequency coefficients are compared with each other based on their location in time and frequency band. The matching coefficients are auto weighted based on their frequency band.

Contributing authors:	Markus Nilsson	Author of paper
Acknowledgements:	Johnny Holmberg	Support in signal theory

Paper F

Markus Nilsson, Peter Funk, Ning Xiong
Clinical decision support by time series classification using wavelets
Accepted for publication at the ICEIS'05 conference, May 2005, Miami, USA

The new retrieval system from paper E has been incorporated in the classification system from paper D. The new design of the system eliminates the need for rules as the time dependent information is captured by the wavelet. A new case reduction method based on clustering is also introduced since the previous method incorporated RBR in it's reasoning process.

Contributing authors:	Markus Nilsson	Main author of paper
		Retrieval ideas + system
	Peter Funk	Ideas for case clustering
	Ning Xiong	Co author of paper
		Case clustering

6 Additional Publications

Paper G: Markus Nilsson, Peter Funk
Classification of psycho-physiological measurements in medical systems
In Proceedings of the SAIS-SSLS 20th Workshop, Working notes, April 2003, Örebro, Sweden.

Paper H: Mikael Sollenborn, Markus Nilsson
Building a Case-Base for Stress Diagnosis: An Analysis of Classified Respiratory Sinus Arrhythmia Sequences
In workshop on CBR in the Health Sciences at ECCBR'04, August 2004, Madrid, Spain.

Thesis I: Markus Nilsson
A Case-Based Approach for Classification of Physiological Time-Series
Licentiate thesis No. 28, May 2004, Mälardalen University Press, Västerås, Sweden.

7 Future Work and Time-Plan

The time plan of the remaining work is divided in to three parts, courses, articles and other (additional) work that effects the time plan.

Courses A total of 50 credits is required for the doctoral thesis and a total of 37 credits is previously completed, 13 additional credits are remaining. The remaining credits are divided in two courses, a digital signals course (DSP) and a machine learning course (ML). The DSP course will give 8 credits and the ML 5 credits, thus make it a total of 50 credits. The courses are displayed in section 8.

Articles The journal paper (paper A) is accepted, but will most likely have to be revised one additional time before the print. This will likely be in february-march. Paper E is also accepted for publication, the camera ready copy will have to be written and submitted no later than february 4th (deadline). The last paper in the thesis, paper F, is pending publication as the camera ready version is submitted.

Other work Additional work that take time is the supervision of 1 or 2 diploma work projects. These projects will be ongoing during the spring and requires extra work parallel to the *Courses* and *Articles*. Parts of march and april will have to be devoted to the organization of the annual SAIS-SSLS workshop that will be held at/by our department 12-14 april. Parts of may will be dedicated to the presentation of paper E at the FLAIRS conference and for paper F at the ICEIS conference. Time will also be devoted during the spring to the analysis of heart signals, as a part of a cooperation project with Uppsala University and Karolinska Institutet.

The remaining work for the doctoral thesis can be composed to the following list of activities:

Major Remaining Activities	**Deadline**
Present this Ph.D. proposal	Febuary
Complete the ML course	March
Complete the DSP course	April
Finding an opponent and a grading committee	April
Presenting papers E & F	May
Completion of doctoral thesis	August
Doctoral thesis defense	September

8 Graduate Courses

Course	**Credits**	**Status**
Research methodology for Computer Science and Engineering	5p	Completed
Science planning for PhD students	5p	Completed
Sensors and wireless systems	2p	Completed
Case Based Reasoning	5p	Completed
Psychophysiological medicine	5p	Completed
Digital signal theory	8p	Ongoing
AI advanced course	5p	Completed
Distributed realtimesystems	5p	Completed
Autonomous robotics	5p	Completed
Machine Learning	5p	Ongoing
Total credits	50p	

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