NPRP

Progress Report Number 5

Project Number

NPRP 4 - 1303 - 2 – 517

Project Title

Automated Neonatal EEG quality assessment and improvement using artefact filtering and signal segmentation

Date: September 2015

Authors: B. Boashash[1,2,3] and Paul Colditz[2,3]

Sponsor:

Qatar National Research Fund

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[2] The University of Queensland, Perinatal Research Centre, School of Medicine, Brisbane, Australia
3 The University of Queensland, UQ Centre for Clinical Research, Brisbane, Australia

Progress Report View

Proposal Number:	NPRP 4 - 1303 - 2 - 517	**Awarded Amount:**	$1,049,943.69	**Sub. Institution:**	Qatar University		
Project Status:	Award Active	**Start Date:**	01-Apr-2012	**Lead Investigator:**	Prof. Boualem Boashash	**Lead Institution:**	
Current Year:	Year 3 of 3	**End Date:**	15-Sep-2016	**Proposal Title:**	Automated Neonatal EEG quality assessment and improvement using artefact filtering and signal segmentation		
Report Type:	Interim	**Report Period:**	5	**Report Status:**	QNRF Accepted	**Version Number:**	1
Due Date:	18-Sep-2015	**Submitted Date:**	15-Sep-2015	**Vetted Date:**	30-Sep-2015		

Research Progress

Aim 3: Design of Algorithms for EEG artefact detection

Start Month	End Month	Completed?	Completed Percentage
1	36	No	82%

Tasks associated with this aim for this period as per the original proposal:

Develop algorithms for automated detection of abnormalities and artifact in EEG signals.

Have you experienced any difficulties?: No

Progress made, accomplishments achieved, and plans to tackle the difficulties listed above (if any):

We used a multi-class signal classification strategy to integrate the artifact detection algorithm with the seizure detection algorithm to improve the performance of overall signal classification algorithms in terms of sensitivity, specificity and accuracy. In addition, a wrapper based sequential feature selection algorithm was implemented to choose the set of best performing (t,f) features. The work is being further refined with the intention to submit it to the Elsevier Digital Signal Processing journal.

Supporting Documents

Aim3-Supporting-document-DSP_part2_July_12_2015.pdf

Aim 4: Artefact Removal from Neonatal EEG

Start Month	End Month	Completed?	Completed Percentage
1	36	No	82%

Tasks associated with this aim for this period as per the original proposal:

1) Remove artifacts from neonatal EEG without estimating a reference signal or underlying EEG characteristics; 2) estimate the underlying EEG characteristics which will be used as references for artifact removal.

Have you experienced any difficulties?: No

Progress made, accomplishments achieved, and plans to tackle the difficulties listed above (if any):

1) Artifact rejection (artifact removal without a reference signal): This approach does not require any reference signal (or estimate) as EEG segments corrupted by artifacts are removed by the classifier at the decision stage. To implement a completely automated EEG signal classification system, we used the following 2 approaches to reject EEG segments contaminated by artifacts: a)binary classification: this approach considers both artifacts and EEG background as one class and abnormalities as another class; b)multi-class classification: this approach trains separate classifiers for detecting background, abnormalities and artifacts. Our recent study showed that the 2nd approach rendered better classification results. The performance is being further improved by incorporating the wrapper based features selection, high resolution QTFDs, and feature level fusion of data acquired from multiple sensors. 2) Artifact correction (artifact removal with reference signals): This approach eliminates artifacts from EEG signals using blind source separation algorithms. To further improve the performance of existing blind source separation algorithms that fail to separate artifacts from original EEG signals, a time-frequency filtering algorithm is being developed. This algorithm uses high resolution TFDs to first estimate the instantaneous frequency (IF) of close signal components. The IF information is then used to extract signal components from the source. The independent channels that are corrupted by artifacts are identified either manually or automatically using correlation with reference signals. The artifact free signal is then synthesized by combining only artifact free EEG segments. This algorithm has been applied to remove simulated respiratory artifacts from simulated EEG seizure signals (see uploaded document). We are currently refining this algorithm for real-life EEG signals.

Supporting Documents

EEG_artifact_removal_using_BSS.pdf

Aim 5: Development of an EEG quality measure

Start Month	End Month	Completed?	Completed Percentage
24	36	No	40%

Tasks associated with this aim for this period as per the original proposal:

Development of EEG quality measure.

Have you experienced any difficulties?: No

Progress made, accomplishments achieved, and plans to tackle the difficulties listed above (if any):

Progress made, accomplishments achieved, and plans to tackle the difficulties listed above (if any): An EEG quality measure is being developed based on the ratio of artifacts and abnormalities over the normal EEG recordings. Supporting Documents

Supporting Documents

Aim 6: Design of Advanced Methods and Algorithms for Time-Frequency Signal and Array Processing.

Start Month	End Month	Completed?	Completed Percentage
12	36	No	95%

Tasks associated with this aim for this period as per the original proposal:

1) Design of high resolution TFDs for the analysis of multi-channel signals. 2) Develop new multi-component IF estimation and blind source separation algorithms.

Have you experienced any difficulties?: No

Progress made, accomplishments achieved, and plans to tackle the difficulties listed above (if any):

We have refined fixed kernel and adaptive kernel time-frequency distributions based on independent reviewers' comments. A research paper based on the adaptive kernel method was accepted for publication in the Journal of Adaptive Control and Signal Processing (See doi:10.1002/acs.2583.). In addition, a few time-frequency post-processing methods were also developed. A book chapter based on these contributions has now been accepted for publication in the book of Time-Frequency Signal Analysis and Processing: A Comprehensive Reference, 2nd Edition (see attached document).

Supporting Documents

Post-processing_in_the_t-f_domain_methods_and_performance_comparison.pdf

Aim 7: Efficiently Lead and manage the project, and supervise the research to ensure outcomes, and organize

Start Month	End Month	Completed?	Completed Percentage
1	36	No	82%

Tasks associated with this aim for this period as per the original proposal:

1) provide overall guidance to the research team, 2) coordinate the efforts at Qatar University and University of Queensland to maximize efficiency and outcomes; and control project activities to keep it within the objectives, 3) organize regular meetings of the research team to optimize consensus management and relevant information circulation among the research partners, 4) ensure quality administrative and financial management of the project, including appointments; and 5) ensure timely, high impact and effective research outputs.

Have you experienced any difficulties?: No

Progress made, accomplishments achieved, and plans to tackle the difficulties listed above (if any):
The lead PI is effectively managing and supervising the research activities in the University of Queensland and Qatar University. Recently a research paper entitled "Multi-component instantaneous frequency estimation using locally adaptive directional time frequency distributions" has been accepted for publication by the Journal of Adaptive Control and Signal Processing (See doi:10.1002/acs.2583.)

Supporting Documents

Future Plan

Aim 3: Design of Algorithms for EEG artefact detection		
Start Month	**End Month**	**Tasks associated with this aim for the next reporting period:**
1	36	A study based on our contribution to the multi-channel EEG signal classification algorithm that uses the wrapper approach to feature selection for the detection of artifacts and abnormalities is being completed with the intention to extract from it a paper to submit to the journal of digital signal processing.

Aim 4: Artefact Removal from Neonatal EEG		
Start Month	**End Month**	**Tasks associated with this aim for the next reporting period:**
1	36	The blind source separation algorithm will be tested and further refined for real-life EEG signals corrupted by artifacts.

Aim 5: Development of an EEG quality measure		
Start Month	**End Month**	**Tasks associated with this aim for the next reporting period:**
24	36	An automated algorithm to assess the quality of the EEG signal based on the percentage of artifacts detected will be further refined.

Aim 6: Design of Advanced Methods and Algorithms for Time-Frequency Signal and Array Processing.		
Start Month	**End Month**	**Tasks associated with this aim for the next reporting period:**
12	36	This aim is now almost complete; what remains is to test and further refine the algorithms already developed.

Aim 7: Efficiently Lead and manage the project, and supervise the research to ensure outcomes, and organize		
Start Month	**End Month**	**Tasks associated with this aim for the next reporting period:**
1	36	The lead PI will continue the effective management and supervision of the project to deliver desired outcomes.

Collaborator Contributions

#	Team Member	Role	Contributions
1	Prof. Boualem Boashash	Lead PI/ Co-Lead PI	I have led the project and coordinated with all co-workers so as to ensure desired outcomes. I have prepared a number of reports, journal and book-chapter submissions/publications (see supporting documents and appendices 1, 2 and 3). Technically, I have contributed to all aims. I have however focused on Aim 6 which is now almost complete; the emphasis was to have the theory implemented in a way that is practical and can be

			applied to Aims 4 and 5; what is currently required is then to consolidate the algorithms so as to make them robust and easy to use in a variety of situations. I have also directed the work for Aims 4 and 5 so that the algorithms developed match the nature of the data available. I have also liaised with the PI and Postdoc in Australia to ensure that the data provided are of the highest possible quality. The current status of my work is testing a new algorithm for component separation for artefact removal. In order to progress faster, I have searched and appointed a number of consultants with relevant expertise.
2	Prof. Paul Colditz	PI	I have focussed on the data annotation and delivery to Qatar. Specifically there has been a need to identify the types of artefact and in particular sort out those with a basis in recording conditions that should be amenable to improvement in the recording environment if identified as such, and those with a physiological basis such as movement, muscle activity etc. The former lead to the possibility that real time feedback could result in better quality signal in the recordings. In addition some signal features such as isolated transients have been identified with their corresponding channel representation to address issues such as signal decay. This has been achieved by me working in liaison with the paediatric neurologist, Dr Shabeed Chalakadan at the Lady Cilento Children's Hospital in Brisbane. PhD student supervision and a focus on specific elements of the artefact analysis as well as general management of the project at the University of Queensland has also been a contribution during this report period. I have assisted the lead PI to ensure satisfactory progress of the project by involvement in the project management particularly at the Brisbane site.
3	Prof. Geraldine Boylan	PI	na

Research Training, Careers and Employment

Number of postdoctoral fellows involved:	1	**For each, list name, contribution, affiliation, and state if inside or outside Qatar:**	Nabeel Ali Khan. Contributions: 1) A paper for the IF estimation of close signal components now is accepted for publication in International Journal of Adaptive Control and Signal Processing (aim#6). 2) A study based on contribution on the simultaneous

			detection of artifacts to improve the signal classification accuracy is being finalized (aim#2). 3) Artifact removal algorithm based on time-frequency filtering is refined and tested for simulated artifacts. (aim#4). Affiliation: Qatar University. Inside Qatar.
Number of graduate students involved:	1	**For each, list name, contribution, affiliation, and state if inside or outside Qatar:**	Mohamed Abdul Awal. Contribution: 1) data marking (aim#1), 2) abnormality detection and artefact removal (aims#3,4), 3) time-frequency analysis method development (aim#6) Affiliation: University of Queensland. Outside Qatar.
Number of full-time research associates/assistants funded:	1	**For each, list name, contribution, affiliation, and state if inside or outside Qatar:**	Shiying Dong. Contribution: EEG with artifact data acquisition, EEG pre-processing, EEG quality measurement, time frequency analysis, design and implementation of algorithms. Outside Qatar.
Number of part-time research associates/assistants funded:	1	**For each, list name, contribution, affiliation, and state if inside or outside Qatar:**	Ayat Salim. Contribution: Literature search, LaTex editing, testing algorithms, time-frequency analysis, Matlab code checking, etc. Affiliation: Qatar University, inside Qatar.
Number of professional and/or technical officers:	0	**For each, list name, contribution, affiliation, and state if inside or outside Qatar:**	NA
Number of other personnel	2	**For each, list name,**	Abdeldjalil Aïssa-El-Bey. Contribution as a consultant:

involved:		**contribution, affiliation, and state if inside or outside Qatar:**	Reviewing and testing algorithms and methods. Affiliation: telecom bretagne university. Inside Qatar. Ervin Sejdić. Contribution as a consultant: Reviewing and testing algorithms and methods. Affiliation: University of Pittsburgh. Inside Qatar

Research Outcomes

Has your research project generated publications during the funding period covered by this progress report (excluding 'accepted', 'forthcoming' and 'submitted' papers)?	No

Publication Type	Title	Authors	Reference No	Abstract	Document
No publications uploaded to this progress report.					

Potential IP

Question	Answer
1. Has your research resulted in a new process, technique, composition of matter, device, software, database, new use or improvement to an existing process?	**Yes**
We have developed new EEG signal analysis and processing tools.	
2. Have you previously disclosed your research results through a presentation or publication? Do you intend to disclose your research results in the next 6 months in the absence of an NDA, for example, through a conference presentation or journal publication? Please provide details	**Yes**
We have published a paper entitled "Time–frequency features for pattern recognition using high-resolution TFDs: A tutorial review" in the digital signal processing journal. In addition, we have a paper accepted in the journal of adaptive control and signal processing (see appendices).	
3. Have you previously filed an invention disclosure within the scope of this research grant?	**No**

N/A	
4. Do you intend to file any invention disclosures within the scope of this research project?	**No**
N/A	
5. Has a patent application been filed under the research project? If yes, when, where, and by whom was the application filed?	**No**
N/A	
6. What is the stage of development (pre-prototype, prototype tested, untested prototype)? How much more technical development is required in terms of time and investment needed to achieve? Please indicate the Technology Readiness Level, see here	**N/A**
We are at the initial level TRL1	
7. To whom do you need to report project IP? What is your understanding of the ownership of the IP?	**N/A**
I need to report to the Office of Research at Qatar University. My understanding of the ownership is that it is jointly owned by QNRF, Qatar University and the external university.	
8. Have any individuals/consultants participated in the research project? If yes, please specify details of the individual (period of collaboration, institution). Was this arranged formally through the relevant Technology Transfer Office?	**No**
N/A	
9. Do you believe your project would benefit from an assessment of the technology asset portfolio developed and the potential market opportunity?	**No**
N/A	

Equipment

Equipment Name	Quantity	Serial Number	Location	Purpose	
No records available					

Travel

From Origin to Destination(s)	Start Date	End Date	Traveler(s) Name(s)	Purpose	
Doha, Qatar to Brisbane, Australia	01-Aug-2015 12:00 AM	31-Aug-2015 12:00 AM	Boualem Boashash	1) coordinated the activities of the research team in Australia via meetings and technical discussions. 2) discuss the data labeling; study the different classes of artifacts and the best approach to design algorithms for artifact removal and enhance signal quality.	

Appendices

Document Name	Document File	Uploa By
Design of High-Resolution Quadratic TFDs with Multi-Directional Kernels	**Design_of_High-Resolution_Quadratic_TFDs_with_Multi-Directional_Kernels.pdf**	
Defining Time-Frequency Image	**Defining_Time-Frequency_Image_Features_by_Extension_from_Frequency_Domain_or_Time_Domain.pdf**	

Document Name	Document File	Uploa By
Features by Extension from Frequency Domain or Time Domain		
Post-processing in the t-f domain: methods and performance comparison	**Post-processing_in_the_t-f_domain_methods_and_performance_comparison.pdf**	
Multi-component instantaneous frequency estimation using locally adaptive directional time frequency distributions	**Multi-component_instantaneous_frequency_estimation_using_locally_adaptive_directional_time_frequency_distributions.pdf**	

Document Name	Document File	Uploa By
Time-frequency features for pattern recognition using high-resolution TFDs_A tutorial review	**Time-frequency_features_for_pattern_recognition_using_high-resolution_TFDs_A_tutorial_review.pdf**	

Expenditure Report

Inside Effort Days	Outside Effort Days	Equipment Cost	Personnel Cost	Travel Cost	Miscellaneous Cost	Indirect Cost	Outside Cost %	Remarks
312	151	$0.00	$45,671.00	$0.00	$0.00	$9,130.00	0	

Report Status History

Date	Version	Status	Action By	Remarks
15-Sep-2015	1	Submitted	Prof. Boualem Boashash	Submitted by Lead
30-Sep-2015	1	RO Vetted	Mrs. Abeer Raie	Vetted by RO
04-Oct-2015	1	QNRF Accepted	Ms. Buthaina Al Hashmi	QNRF Accepted by QNRF