NPRP

Progress Report Number 4

Project Number

NPRP 6 - 885 - 2 – 364

Project Title

Localization of EEG Abnormalities for Improving Brain Monitoring of Newborn Babies at Risk of Brain Injury using a multichannel time-frequency signal processing approach

Date: February 2016

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

Sponsor:

Qatar National Research Fund

[1] College of Engineering, Qatar University, Qatar
[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

Report Information

Proposal Number:	NPRP 6 - 885 - 2 - 364	**Awarded Amount:**	$1,050,000.00	**Sub. Institution:**	Qatar University
Lead Investigator:	Prof. Boualem Boashash	**Lead Institution:**			
Project Status:	Award Active	**Start Date:**	23-Feb-2014	**End Date:**	23-Jun-2017
Current Year:	Year 3 of 3	**Report Type:**	Interim		
Report Period:	4	**Report Status:**	QNRF Accepted	**Version Number:**	1
Due Date:	13-Feb-2016	**Submitted Date:**	16-Feb-2016	**Vetted Date:**	25-Feb-2016

Proposal Title: Localization of EEG Abnormalities for Improving Brain Monitoring of Newborn Babies at Risk of Brain Injury using a multichannel time-frequency signal processing approach

Research Progress

Aim 1: EEG Data acquisition, labelling, and pre-processing

Start Month: 1 **End Month:** 36 **Completed?** No **Completed Percentage:** 70%

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

1) Continuously collect newborn multichannel EEG data to make an adequate dataset. 2) Consolidate different data-sets for more accurate results and comparisons.

Have you experienced any difficulties?: No

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

We have continuously acquired newborn multichannel EEG data to consolidate and authenticate the achieved results for the detection/classification of newborn EEG abnormalities. Apart from this, we have also made progress in acquiring EEG data for (AIM4). This dataset is already prepared for testing and validating newborn EEG source localization techniques that are under development. In this regard, the team in the University of Queensland, Brisbane, Australia has been conducting work related to this task: 1) labeling local transients in the newborn EEG by a paediatric neurologist; 2) examining localized sensory neural responses to stimulus to the baby's hand in EEG signals.

Supporting Documents

Aim 2: EEG Abnormality detection using multi-channel t-f signal analysis methods

Start Month: 1 **End Month:** 30 **Completed?** No **Completed Percentage:** 85%

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

(1) Further improve and analyze the multi-channel features' fusion and multi-classifier approaches for the detection of abnormalities, (2) develop new features that can improve the EEG abnormality detection performance, (3) perform illustration of the new features on realistic neonatal multichannel EEG signals (4) publish the results in a top level journal.

Have you experienced any difficulties?: No

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

We have continued our work to design new high resolution time-frequency distributions (TFDs) and study their impact on the extraction of features for better detection of abnormalities in the neonatal multichannel EEG. We have further developed and analyzed the multi-channel feature fusion and multi-classifier approaches to the detection of abnormalities by including performance comparison of new features and new machine learning techniques. In addition, different high resolution TFDs (recently developed by the research team) are being exploited and illustrated on neonatal EEG signals for detection. The results are being

compared with other existing methods and a manuscript on this work is being drafted for submission in a top level journal. Part of this study has contributed to several chapters in the recently released second edition of the book “Time-frequency signal processing: a comprehensive reference.”

Supporting Documents

- Art_16.3_Final.pdf
- Art_16.6_Final.pdf
- Art_15.5_Final.pdf

Aim 3: Designing a head model for neonates

Start Month: 1 **End Month:** 12 **Completed?** No **Completed Percentage:** 90%

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

Verify and calibrate the developed newborn head model using segmented MRI data.

Have you experienced any difficulties?: Yes

Progress on this aim has been delayed by a staffing issue in the University of Queensland site where the Research Associate, Dr Shiying Dong has resigned from full-time employment and has been working only part –time since September 2015. We have experienced a delay in obtaining a full time commitment because

an appropriately qualified Research Associate we have identified has not yet obtained the necessary Australian work visa.

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

In addition to maintain a realistic neonatal head model and the corresponding multichannel EEG, we have also constructed a synthetic End-to-End EEG system by using a synthetic neonatal head model, 21 EEG electrodes and signal propagation models. This synthetic model will be used for the analysis of the recently developed algorithms for the detection/classification /localization of seizures and artifacts. Such an emulator will also be used as a tool for understanding the field of Time-Frequency analysis and its application in neurosciences. The completion of this aim has not yet been achieved because we are attempting to develop innovative signal processing techniques (as described above) associated with this aim instead of using existing methods to calculate the newborn head model as we described in the application. We have full neonatal brain MRI datasets and automated segmentation approaches, which is a critical step in the head model. This when combined with the lead field matrix which we will do using software already developed provides completion of this aim. Whilst we await a full time Research Associate commitment, we have in place a current PhD scholar who has relevant background experience and under the guidance of the PI has developed the necessary skills to undertake major aspects of the remaining work to be done.

Supporting Documents

Aim 4: EEG source localization, and validation of the techniques developed

Start Month: 13 **End Month:** 36 **Completed?** No **Completed Percentage:** 55%

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

1) Extend the already developed localization technique for sources of non-disjoined signatures in the (t,f) plane by exploiting image processing techniques, 2) improve the estimation of instantaneous frequencies (IFs) of non-disjoined sources, 3) use the accurate IF estimates for achieving improved localization of non-disjoined sources, 4) extend our work on source localization to more generalized cases (disjoined, non-disjoined, underdetermined).

Have you experienced any difficulties?: No

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

The already developed localization techniques based on time-frequency analysis are being extended to localize signal sources with non-disjoined signatures in the time-frequency plane. For this purpose, we have studied image processing techniques to better estimate the instantaneous frequencies (IFs) of non-disjoined sources. The estimated IFs allow us to achieve accurate localization of the non-disjoined sources in the underdetermined cases. Development of such algorithms will extend our work on source localization to a more generalized case that considers both disjoined and non-disjoined sources. Two articles are being published in the new 2nd edition “Time-frequency signal processing: a comprehensive reference”. In addition a tutorial paper is being prepared for

submission to Elsevier Digital Signal Processing with the title “Multivariate Time-Frequency Signal Processing: a tutorial review with illustrations from multichannel EEG”. We have also been developing a synthetic neonatal head model (initially a spherical model, now being extended to a more realistic head shape model) that can be effectively used to define the performance characteristics of the recently developed algorithms for localizing EEG abnormalities in the newborn brain.

Supporting Documents

- Art_16.1_Final.pdf
- Art_16.2_Final.pdf
- ACKNOWLEDGMENTS.pdf

Aim 5: Connectivity analysis for EEG abnormality characterization at both scalps and source levels

Start Month: 19 **End Month:** 30 **Completed?** No **Completed Percentage:** 30%

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

(1) Perform a literature survey on the recent developments of connectivity analysis
(2) develop new methods for the connectivity analysis and use them to study the interactions between brain cortical areas for different newborn EEG abnormalities.

Have you experienced any difficulties?: No

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

We have completed the literature survey and initial framework for the connectivity analysis. Study of the following techniques has been performed including cross-correlation coefficient, mutual information imaginary coherence and phase synchronization. Theoretical development of relevant methods has been initiated. Since AIM5 is dependent on substantial progress/completion of AIMs 3 & 4, further progress will be made with completion of these Aims. From the initial studies, outcomes have been accepted in the form of two book articles in the 2nd edition of "Time-frequency signal processing: a comprehensive reference".

Supporting Documents

- ACKNOWLEDGMENTS.pdf
- Art_5.11_Final.pdf
- Art_16.4_Final.pdf

Aim 6: Design of new Time-Frequency Signal Processing methods including theory, algorithms and implementati

Start Month: 1 **End Month:** 36 **Completed?** No **Completed Percentage:** 70%

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

(1) Continue to develop new time-frequency methods associated with Aims 2-5,
(2) design novel time-frequency techniques to improve the readability and

parameter (e.g., IF, features) estimation capabilities of time-frequency distributions.

Have you experienced any difficulties?: No

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

We have continued our analytical as well as numerical analysis to design new efficient TFDs that lead to the design of more accurate multi-component IF estimators, needed for the successful completion of different AIMs of this project. We are also designing adaptive and signal dependent TFDs. One such technique based on the Adaptive Modified B-Distribution (MBD) is being developed by the LPI and co-authors, and can be used to accurately compute the IFs of closely placed signal components at a very low SNR. TFDs are functions of two variables (time & Frequency); they require significant time and memory to compute and store in digital devices, such as personal computers or field programmable gate array (FPGA). This is particularly evident for EEG signals, when long-duration multichannel recordings can create large data sets. Hence, we have also initiated work to design high resolution TFDs that are memory efficient and have less computational complexities. Four articles are published in the new 2nd edition "Time-frequency signal processing: a comprehensive reference".

Supporting Documents

- Articles_5.5_and_5.12.pdf

- Art_6.5_Final.pdf
- Art_7.4_Final.pdf

Aim 7: Project Management and Coordination

Start Month: 1 **End Month:** 36 **Completed?** No **Completed Percentage:** 67%

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

(1) Provide guidance to the research team, (2) coordinate the efforts at Qatar University and University of Queensland, (3) control project activities to keep it within the objectives, (4) organize regular meetings of the research team to ensure consensus management and information circulation among the research partners, (5) ensure quality administrative and financial management of the project, and (6) ensure timely, high impact and effective research outputs in the form of book, articles and conferences.

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 supervising the activities in the project both at the Qatar University and the University of Queensland, Brisbane Australia. The two research

groups (one in Qatar University and the other in the University of Queensland, Australia) are working in close coordination to achieve satisfactory results. Recently, based on the collaborative efforts and effective supervision by the lead PI, multiple articles/chapters have been contributed by the research team in the 2nd edition of Elsevier book having title “Time-frequency signal processing: a comprehensive reference”. In addition, under the supervision of the lead PI, one journal paper has been submitted in a special issue on “Advanced Signal Processing in Brain Networks” in IEEE Transaction in Signal Processing and two other papers are under preparation to be submitted to Elsevier Digital Signal Processing and Elsevier Signal Processing.

Supporting Documents

- Articles_5.5_5.11_and_5.12.pdf
- Articles_6.5_and_7.4_from_TFSAP.pdf
- Articles_16.1_16.2_and_16.4_from_TFSAP.pdf

Future Plan

Aim 1: EEG Data acquisition, labelling, and pre-processing

Start Month
1

End Month
36

Tasks associated with this aim for the next reporting period
We will continue acquiring data to increase the database size for developing and validating EEG abnormality detection/ classification techniques and source localization algorithms.

Aim 2: EEG Abnormality detection using multi-channel t-f signal analysis methods

Start Month
1

End Month
30

Tasks associated with this aim for the next reporting period
We will further develop and analyze the current multi-channel feature fusion and multi-classifier approaches to the detection of EEG abnormalities. We will include new features such spatial correlation between different channels or temporal correlation within each channel and adopt recent machine learning techniques to increase the performance of the detectors and classifiers for multiple new datasets. We will also consider other effective approaches to combining the multichannel EEG data such as combing different channels TFDs then calculating the features. Statistical analysis technique will also be considered and developed for detection and classification of EEG abnormalities. In addition, recent high resolution TFDs will be used to further improve the earlier developments by the research team and publish these results in top level journals.

Aim 3: Designing a head model for neonates
Start Month
1

End Month
12

Tasks associated with this aim for the next reporting period
We will continue to create a new and authentic real head model for the localization of EEG abnormalities (AIM4) and connectivity analysis (AIM5).

Aim 4: EEG source localization, and validation of the techniques developed
Start Month
13

End Month
36

Tasks associated with this aim for the next reporting period
Newly developed MUSIC based localization techniques will be applied and illustrated on both synthetic and real neonatal head models with corresponding EEGs. The MUSIC algorithm will be studied and compared for the cases: 1) time domain 2) Region of Interest Selection in the time-frequency plane using image processing 3) high energy time-frequency points selection and IF estimation in the time-frequency plane using IF estimation techniques 4) using 2) & 3) for the underdetermined case.

Aim 5: Connectivity analysis for EEG abnormality characterization at both scalps and source levels

Start Month
19

End Month
30

Tasks associated with this aim for the next reporting period
1) Use the results of AIMs 1, 2 and 4 to study the physical location of the different scalp level abnormalities. 2) Track the behavior of the sources in the brain when the abnormality spreads or migrates from one part of the scalp to another.

Aim 6: Design of new Time-Frequency Signal Processing methods including theory, algorithms and implementati
Start Month
1

End Month
36

Tasks associated with this aim for the next reporting period
We will continue our work to develop time-frequency methods associated with Aims 1, 2, 4 & 5 and improve these methods in terms of accuracy and implementation efficiency. We will focus on the analytical research in designing new high resolution TFD algorithms keeping the following two aspect particularly in consideration • Reduced computation time and memory load. • Signal-dependent adaptive TFDs The team will continue work to develop novel methods for obtaining high-resolution time-frequency representation based on short-time fractional Fourier transform (STFrFT). This TFD will be derived from ‘Optimal Spectrogram’, that automatically determines the optimal window parameters and fractional order (angle) for all signal components (local optimization) to obtain high resolution and cross-term free time-frequency representation. This method will be suitable for multicomponent and non-stationary signal without priori signal information. The newly developed TFDs will be illustrated on neonatal EEG for Localization/Detection/Classifications of abnormalities and connectivity analysis. After successful completion of the work, a research article titled “Robust high-resolution time-frequency representation based on short-time fractional Fourier transform” will be submitted to Elsevier Signal Processing.

Aim 7: Project Management and Coordination
Start Month
1

End Month
36

Tasks associated with this aim for the next reporting period

(1) Provide guidance for the research team, (2) Ensure quality administrative and financial management of the project; (3) Develop a spirit of co-operation between the partners; (4)Ensure consensus management and information circulation among the partners; (5)Coordinate and control project activities to keep it within the objectives.

Collaborator Contributions

#	Team Member	Role	Contributions
1	Prof. Boualem Boashash	Lead PI/ Co-Lead PI	My contribution includes leading the project, searching for suitable research personnel, contributing ideas and algorithm design approaches, drafting the outline of research publications and reviewing/editing the drafts as the various sections get completed. I also check the algorithms to ensure they work as expected. The most significant contribution this time has been to finalize the 2nd edition of the Academic Press book "Time-Frequency Signal Analysis and Processing...." published in December 2015. An acknowledgment to this NPRP grant is included in the Preface (see Appendix). This book has over 1000 pages and it has already 1500 citations according to Harzing Publish and Perish website, including of course those coming from the 1st edition. Other standard contributions include organizing visits to the Australian side to ensure the progress is on track and address the issue of the difficulty of recruiting suitable postdocs for this project as well as the issue of the data required for the project continuation.
2	Prof. Paul Colditz	PI	I have focused on facilitating data annotation and furthering the analysis of the sensory neural responses to stimulus to the baby's hand in EEG signals. 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 and to ensure appropriate identification of the sensory stimulation data in the EEG. This has been achieved both independently and by me also working in liaison with the paediatric neurologist, Dr Shabeed Chalakadan at the Lady Cilento Children's Hospital in Brisbane. I have a close role in 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. I have also assisted the lead PI to ensure satisfactory progress of the project by involvement in the project management particularly at the Brisbane site.

Research Training, Careers and Employment

Number of postdoctoral fellows	1	**For each, list name, contribution,**	Sadiq Ali, Contributed to Aims 2, 3, 4 and 6, Qatar university, inside Qatar.

involved:		**affiliation, and state if inside or outside Qatar:**	
Number of graduate students involved:	3	**For each, list name, contribution, affiliation, and state if inside or outside Qatar:**	Mohamed Abdul Awal, worked on EEG labelling (aim#1), EEG abnormality detection (aim#2) and TFD algorithm development (aim#6), the University of Queensland, Australia; Tim Sherry, worked on EEG abnormality detection (aim#2) and lead field matrix calculation for head modeling (aim#3), the University of Queensland, Australia; Mohammad Fathi Al-Sa'D, contributed to Aim 2, Aim 3 and Aim 4, submitted his Masters thesis with intention to write a paper out of it, Qatar University, Qatar.
Number of full-time research associates/assistants funded:	0	**For each, list name, contribution, affiliation, and state if inside or outside Qatar:**	NA
Number of part-time research associates/assistants funded:	1	**For each, list name, contribution, affiliation, and state if inside or outside Qatar:**	Dr. Shiying Dong, worked on EEG and MRI data acquisition and labelling (aim#1), EEG abnormality detection (aim#2) and TFD and IF estimation methods development (aim#6), the University of Queensland.

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 involved:	0	**For each, list name, contribution, affiliation, and state if inside or outside Qatar:**	NA

Research Outcomes

Has your research project generated publications during the funding period covered by this progress report (excluding 'accepted', 'forthcoming' and 'submitted' papers)? Yes

Publication Type	Title	Authors	Reference No	Abstract	Document
Journal Paper	EEG background features that predict outcome in term neonates with hypoxic ischaemic encephalopathy: A structured review	Prof. Boualem Boashash, Prof. Paul Colditz	ISSN:13882457	Objectives: Hypoxic ischaemic encephalopathy is a ...more	File
Book	Time-Frequency Signal Analysis and Processing, 2nd Edition: A Comprehensive Reference	Prof. Boualem Boashash	ISBN:9780123984999	Description Time-Frequency Signal Analysis and Pr... more	File

Potential IP

1. Has your research resulted in a new process, technique, composition of matter, device, software, database, new use or improvement to an existing process?

Answer

Yes

Comments

We have published the new results discussed in the section on Research Outcomes.

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

Answer

Yes

Comments

See list of publications attached

3. Have you previously filed an invention disclosure within the scope of this research grant?

Answer

No

Comments

N/A

4. Do you intend to file any invention disclosures within the scope of this research project?

Answer

No

Comments

N/A

5. Has a patent application been filed under the research project? If yes, when, where, and by whom was the application filed?

Answer

No

Comments

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
Answer
N/A

Comments
This is at the pre-prototype stage. Another two 6-monthly periods are needed before we can have a clear idea. The Technology Readiness Level is TRL 1.

7. To whom do you need to report project IP? What is your understanding of the ownership of the IP?
Answer
N/A

Comments
I need to report to the Office of Research at Qatar University. My understanding of the IP ownership is that it is shared.

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?
Answer
No

Comments
N/A

9. Do you believe your project would benefit from an assessment of the technology asset portfolio developed and the potential market opportunity?
Answer
No

Comments
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-Feb-2016 12:00 AM	11-Feb-2016 12:00 AM	Prof Boualem Boashash	The purpose of the travel is to progress the research project according to the project goals and objectives including specifically addressing the following specific issues. 1) EEG Data acquisition, labelling, and pre-processing: Acquire more multi-channel EEG data to increase the database size and improve protocol with annotation of abnormalities and artifacts . 2) EEG Abnormality detection using multi-channel t-f signal analysis methods: Develop and analyse multi-channel feature fusion methods for the large EEG database. 3) Designing a head model for neonates: Discuss the current segmented neonatal MRI for Lead Field Matrix estimation. 4) EEG source localization, and validation of the techniques developed: Apply the MUSIC algorithm to the Lead Field Matrix. 5) Connectivity analysis: Relate this aim to the constraints from Aims 1,2, 3 and 4 to track the behavior of sources in the brain. 6) Design of new Time-Frequency Signal Processing methods: Present the new toolbox for high resolution TFDs to the team in Australia. 7) Project Management and Coordination: Have discussions about the issue of recruiting suitable Postdocs and RAs for appointment on this project with the PI at University of Queensland.

Appendices

Document Name	Document File	Uploaded By	Uploaded On
Acknowledgment pages of the book "time frequency signal analysis and processing".	ACKNOWLEDGMENTS.pdf	Prof. Boualem Boashash	16-Feb-2016 11:17 AM

Expenditure Report

Inside Effort Days	Outside Effort Days	Equipment Cost	Personnel Cost	Travel Cost	Miscellaneous Cost	Indirect Cost	Outside Cost %	Remarks
238	110	$0.00	$69,999.00	$0.00	$0.00	$13,922.00	0	OAR notified the LPI about the term of the acknowledgment.

Report Status History

Date	Version	Status	Action By	Remarks
16-Feb-2016	1	Submitted	Prof. Boualem Boashash	Submitted by Lead
25-Feb-2016	1	RO Vetted	Mrs. Abeer Raie	Vetted by RO
03-Mar-2016	1	QNRF Accepted	Ms. Buthaina Al Hashmi	QNRF Accepted by QNRF