

AWARD NUMBER: W81XWH-17-C-0238

TITLE: Complete and Resilient Documentation (CARD) for Operational Medical Environments

PRINCIPAL INVESTIGATOR: Kuang-Ching Wang, PhD

CONTRACTING ORGANIZATION: Clemson University, Clemson, SC 29634

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14. ABSTRACT  In response to the HITI HFEHRI solicitation for research to demonstrate and validate hands-free electronic health record data entry solutions that will operate reliably in noisy operational environments, alleviate disruption of care for documentation, and prevent loss of documentation, this project studies a system-oriented approach to meet these objectives with a platform aimed to enable resilient hands-free data collection, preserve complete documentation through stages of care, and present timely information useful for the medical operation.					
15. SUBJECT TERMS Battlefield, Hands-free, Electronic health record, Documentation, Operational environments, Medical Workflow, Stages of care, Speech recognition, Noise, GPU, Deep learning, Neural network, Video, Simulation					
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## **1. INTRODUCTION:**

In response to the HFEHRI (Hands-Free Electronic Health Record Data Entry Initiative) solicitation for research to demonstrate and validate hands-free electronic health record data entry solutions that will operate reliably in noisy operational environments, alleviate disruption of care for documentation, and prevent loss of documentation, this project studies a system-oriented approach to meet these objectives with a platform aimed to enable resilient hands-free data collection, preserve complete documentation through stages of care, and present timely information useful for the medical operation.

## **2. KEYWORDS:**

Battlefield  
Hands-free  
Electronic health record  
Documentation  
Operational environments  
Medical  
Workflow  
Stages of care  
Speech recognition  
Noise  
GPU – Graphics processing unit  
Deep learning  
Neural network  
Natural language processing  
Video analysis  
Simulation

## **3. ACCOMPLISHMENTS:**

### **What were the major goals and objectives of the project?**

The project has the following four specific aims:

- Medical Workflow Studies – By conducting focus group interviews, EMS simulation drills, and identifying medical workflow driven performance metrics for CARD, this aims to inform the CARD platform design goals and assessment methods.
- Platform Development – By integrating camera and data storage to GPU-based embedded computer, developing deep-learning based speech recognition and video analysis software with focus on military operation conditions, and integrating with DoD’s digital medical data platforms (TCCC card and Cerner EHR), this aims to create an extensible, prototype for CARD and to demonstrate the complete technology workflow from creating training data sets to identifying performance enhancement methods.

- Assessment – This assesses performance of the technology, the quality of recorded clinically relevant data in the TCCC format, and the level of acceptance by EMS professionals in simulated medical operations.
- Roadmap Development – This aims to derive recommendations of a technology maturation roadmap for the CARD technologies.

**a. What was accomplished under these goals?**

The project was originally planned with a two-year duration. Two 6-month no-cost extensions and one 1-year no-cost extensions have been granted to date, making the current project expiration date to be September 30, 2021. All three extensions have been requested on the basis of further technology development efforts informed by project findings, while the most recent extension was also due partly to impacts by campus closure caused by the COVID-19 pandemic. The project is in its last phase focusing on two tasks - technical publication, and roadmap development.

The proposed CARD platform has been fully implemented by September 2019, with a real-time operation dashboard completed by December 2019. Nevertheless, the team continued to enhance the speech enhancement and recognition algorithms. In this reporting period, one conference paper was accepted for presentation (INTERSPEECH 2020), one more conference paper was submitted, and two more journal papers were in progress.

For assessment, we concluded our third and last simulation drill in the medical simulation center on 12/2/2019. The real-time operation dashboard was developed in time to support this final drill. See photos under Appendix. The drill provided additional video and audio recordings for assessment and further development of the speech and video algorithms.

For roadmap development, we have identified three key gaps in the speech recognition technologies as reported in the March 2020 quarterly report – namely, errors introduced when multiple speakers are present in audio, the lack of additional non-audio inputs for correcting speech recognition errors, and the limited natural language processing algorithms adopted for error detection and correction. The finding guided us to focus our roadmap on enhanced speech separation methods for speech recognition, joint audio-video recognition techniques, and a multitude of natural language processing techniques.

**What opportunities for training and professional development has the project provided?**

The project has graduated one PhD student, and currently supports the research and education of four PhD students and one undergraduate student.

**How were the results disseminated to communities of interest?**

The results have been presented at multiple conferences, including abstracts at MHSRS 2017, 2018 and full papers at INTERSPEECH 2019, INTERSPEECH 2020.

**What do you plan to do during the next reporting period to accomplish the goals?**

In the coming year, efforts will focus on:

- Publication of speech technology at conferences and journals
- Continued roadmap development with validation of selected technical methods

**GANTT CHART INCLUDING EXTENSIONS**

	Y2Q1	Y2Q2	Y2Q3	Y2Q4	Y3Q1	Y3Q2	Y3Q3	Y3Q4
<b>Specific Aim I- Medical Workflow Studies</b>								
<b>Task 1.3: Qualitative Assessment</b>								
Quality assessment instrument design								
Survey execution and analysis								
<b>Specific Aim 2- Platform Development</b>								
<b>Task 2.2: Speech Recognition &amp; Video Digest</b>								
Video digest								
Cerner integration								
Publication of speech technology study								
Natural Language Processing study								
Video Analysis study								

<b>Specific Aim 3 – Assessment</b>	Y2Q1	Y2Q2	Y2Q3	Y2Q4	Y3Q1	Y3Q2	Y3Q3	Y3Q4
<b>Task 3.1: Technology Assessment</b>								
Platform benchmarking								
Drill #2 design and preparation								
Drill #2 execution								
<b>Task 3.2: Workflow and EHR Assessment</b>								
Qualitative Survey of workflow quality								
<b>Specific Aim 4 – Roadmap Development</b>								
Platform Usability and gaps assessment								
Roadmap development								

#### 4. IMPACT:

##### What was the impact on the development of the principal discipline(s) of the project?

Impact on state-of-the-art understanding of speech recognition technology challenges for battlefield environment:

- Deep look into the question “is state-of-the-art speech solutions, either academic or commercial, ready for the battlefield?”
  - Produced systematic benchmarking of two most advanced open source neural network-based speech recognition software by Mozilla (Deep Speech, end-to-end deep learning) and John Hopkins University (Kaldi, hybrid deep learning) with respect to battlefield noise of different types and intensity and concluded severe performance degradation with battlefield noise.
- Build foundations for DoD’s long-term success in speech recognition competencies:
  - Produced systematic assessment and analysis of speech recognition correctness’s dependencies on algorithms, processing, and data (training).
  - Derived approach to systematically assess specific speech recognition enhancement actions with measurable performance impacts
  - Developed modular enhancement methods to enable persistent performance enhancement for hybrid deep learning based speech recognition.
  - Integrated video analysis software for object and action analysis in recorded video.
- Build foundations for DoD’s long-term success in video analysis competencies:
  - Integrated video analysis software for object and action analysis in recorded video.
  - Explored systematic process for DoD to continuously enhance video analysis with contents reflecting DoD operation needs and priorities.
- The research expects significant impacts in:
  - Commercial, Civilian and Military
    - Commercial development in key technologies
    - Synergistic use in civilian EMS, homeland security and disaster recovery
    - New companies or consortium of companies on standard based integrated platform, from variety of data capture devices, mobile app, to cloud solutions
    - Integration with telemedicine, enhance the care and survivability of service members
    - Establish understanding of battlefield readiness of state-of-the-art technology
    - Establish foundations for long-term success for DoD speech recognition competencies

- Academic
  - Speech recognition, natural language understanding, and video analysis in battlefield settings is a rich area for academic research
  - Large scale, distributed data collection (speech, video, sensors) and aggregation into individual patient data is a rich area of research

**What was the impact on other disciplines?**

*Nothing to Report*

**What was the impact on technology transfer?**

*Nothing to Report*

**What was the impact on society beyond science and technology?**

*Nothing to Report*

**5. CHANGES/PROBLEMS:**

**Changes in approach and reasons for change**

*Nothing to Report*

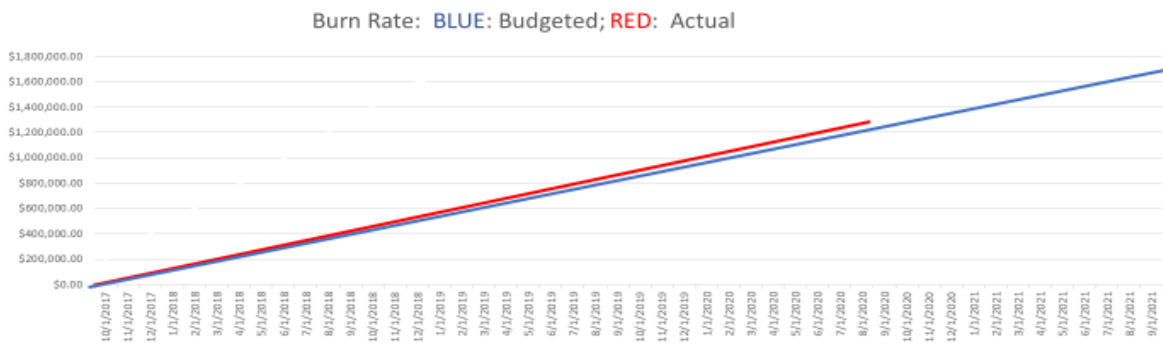
**Actual or anticipated problems or delays and actions or plans to resolve them**

*Nothing to Report*

**Changes that had a significant impact on expenditures**

We have the leverage to spend an additional year working on a few high value investigations.

- ❖ Projected Expenditure: \$1,644,510    Actual Expenditure: \$1,527,749.91 @ 8/31/20
- ❖ Anticipated adjustments on remaining periods – None



**Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents:**

Nothing to Report

**Significant changes in use or care of human subjects:**

Nothing to Report

**Significant changes in use or care of vertebrate animals:**

Nothing to Report

**Significant changes in use of biohazards and/or select agents:**

Nothing to Report

**6.PRODUCTS:**

**Publications, conference papers, and presentations**

**Journal publications**

Nothing to Report

**Books or other non-periodical, one-time publications**

Nothing to Report

**Other publications, conference papers, and presentations**

- Ju Lin, Sufeng Niu, Zice Wei, Xiang Lan, Adriaan J. van Wijngaarden, Melissa C. Smith, Kuang-Ching Wang, "Speech Enhancement Using Forked Generative Adversarial Networks with Spectral Subtraction", in Proceedings of INTERSPEECH 2019, Graz, Austria, Sep. 15-19, 2019.

**Website(s) or other Internet site(s)**

South Carolina ETV article: New research to help injured troops using technology

[https://www.scetv.org/stories/health/2020/new-research-help-injured-troops-using-technology?fbclid=IwAR3IN0hYeqMNqZ\\_8rEGocqA07exvnAnnjc0eJ DhcdmPGRnmESeEh2lPsgSk](https://www.scetv.org/stories/health/2020/new-research-help-injured-troops-using-technology?fbclid=IwAR3IN0hYeqMNqZ_8rEGocqA07exvnAnnjc0eJ DhcdmPGRnmESeEh2lPsgSk)

**Technologies or techniques**

Nothing to Report

**Inventions, patent applications, and/or licenses**

Nothing to Report

**Other Products**

Nothing to Report

**7.PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**

**What individuals have worked on the project?**

Provide the following information for: (1) PDs/PIs; and (2) each person who has worked at least one-person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours of effort). If information is unchanged from a previous submission, provide the name only and indicate "no change."

*Name:* Kuang-Ching Wang (no change)  
*Project Role:* Principal Investigator  
*Research Identifier:* 0000-0002-5675-7104  
*Nearest person month worked:* 2.25  
*Contribution to Project:* Dr. Wang is responsible for all aspects of the research study.

*Name:* Ronald Gimbel (no change)  
*Project Role:* Co-PI  
*Research Identifier:* 0000-0001-8185-4013  
*Nearest person month worked:* 1.0  
*Contribution to Project:* Dr. Gimbel supports Dr. Wang and Dr. Griffin in qualitative research, co-coordinating drill #1, and communication with the Palmetto Health Emergency Medicine team.

*Name:* Sarah Griffin (no change)  
*Project Role:* Investigator  
*Research Identifier:* 0000-0003-4820-3985  
*Nearest person month worked:* 1.0  
*Contribution to Project:* Dr. Griffin will lead focus groups and interviews to glean insight on operational medical workflow.

*Name:* Jerome McClendon  
*Project Role:* Post-Doc  
*Research Identifier:* n/a  
*Nearest person month worked:* 1.0  
*Contribution to Project:* Dr. McClendon assisted with multiple aspects of the CARD technologies research.

*Name:* Minjae Woo (no change)  
*Project Role:* Graduate Student  
*Nearest person month worked:* 12  
*Contribution to Project:* Mr. Woo supports Drs. Gimbel and Griffin in activities related to the proposed qualitative research, statistical analysis and outcome analysis, and issues related to the drills and workflow. The student will also develop the basic model that controls simulation of battlefield noise.

*Name:* Caleb Linduff (no change)  
*Project Role:* Graduate Student  
*Nearest person month worked:* 12  
*Contribution to Project:* Mr. Linduff will focus on platform integration and support Dr. Wang in the area of how to integrate the data into the Cerner electronic health record.

*Name:* Qing Wang  
*Project Role:* Graduate Student  
*Nearest person month worked:* 12  
*Contribution to Project:* Mr. Wang will support Dr. Smith's work on video and speech recognition.

*Name:* Ju Lin (no change)  
*Project Role:* Graduate Student  
*Nearest person month worked:* 12  
*Contribution to Project:* Mr. Lan will support Dr. Smith's work on video and speech recognition.

*Name:* Snigdhaswin Kar  
*Project Role:* Graduate Student  
*Nearest person month worked:* 12  
*Contribution to Project:* Mr. Kar will support Dr. Wang's work on benchmark experiments and publication.

*Name:* Prabodh Kumar Mishra  
*Project Role:* Graduate Student  
*Nearest person month worked:* 12  
*Contribution to Project:* Mr. Mishra will support Dr. Wang's work on benchmark experiments and publication

*Name:* J N Deas  
*Project Role:* Undergraduate Student  
*Nearest person month worked:* 1  
*Contribution to Project:* Mr. Deas will support Dr. Wang's work on benchmark experiments and publication

*Name:* Karen Edwards (no change)  
*Project Role:* Research Associate  
*Research Identifier:* 0000-0003-3584-0328  
*Nearest person month worked:* 1.2  
*Contribution to Project:* Mrs. Edwards assisted with regulatory/IRB approvals from Palmetto Health and Clemson University as well as the approval from the HRPO military secondary review board. She will assist with various reports and logistical items.

*Name:* William Gerard, MD (no change)  
*Project Role:* Co-Investigator  
*Nearest person month worked:* 1.0  
*Contribution to Project:* Dr. Gerard oversees all aspects of the study at Palmetto Health System

*Name:* Stephen Shelton, MD (no change)  
*Project Role:* Investigator  
*Nearest person month worked:* 1.0

*Contribution to Project:*

*Dr. Shelton works alongside Dr. Gerard and the Emergency Department physicians at Palmetto Health System.*

*Name:*

*Kelly Hawsey, RN (no change)*

*Project Role:*

*Investigator*

*Nearest person month worked:*

*1.0*

*Contribution to Project:*

*Mrs. Hawsey assists with logistics of the study at the Palmetto Health System site.*

**Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

*Nothing to Report*

**What other organizations were involved as partners?**

**Organization Name:** Palmetto Health System

**Location of Organization:** Columbia, South Carolina

**Partner's contribution to the project:**

**Financial support:** n/a

**In-kind support:** n/a

**Facilities:** *Project staff use the partner's facilities for project activities.*

**Collaboration:** *Partner's staff work with project staff on the project*

**Personnel exchanges:** *Project staff and/or partner's staff use each other's facilities, work at each other's site.*

**Other:** n/a

**8.SPECIAL REPORTING REQUIREMENTS**

**COLLABORATIVE AWARDS:** n/a

**QUAD CHARTS:** Appendix B

## 9. APPENDICES:

### APPENDIX A - Simulation Drill #2 Photographs

Transport scenario with amputee patient



Hospital scenario with a gunshot wound patient



## Battlefield scenario with a concussion



### Highlights from Simulation Drill #2 on December 2, 2019

Simulation drill #2 was the last drill before this project concludes. It consisted of the following components and emphases:

- Full CARD solution on the NVIDIA TX2-based embedded platform
- Full Kaldi/TensorFlow based speech recognition software with speech enhancement, medical language model, preliminary NLP post-processing, and TCCC card entry
- Monitoring dashboard with live streamed status and speech, video, and TCCC outputs of all (6) active TX2 platforms
- Extended medic scripts covering more data fields in the TCCC card
- Tests under multiple conditions: 1) high vs. low vs. no noise, 3) single vs. multiple speaker, 4) regular vs. speed-up pace of speech
- Improved video camera attachment to medics and recording of point-of-injury surroundings



**Complete and Resilient Documentation (CARD) for Operational Medical Environments**

Log Number: DM160374 W81XWH-17-C-0238

PI: Kuang-Ching Wang

ORG: Clemson University

Award Amount: \$1,644,510

**Study/Product Outcome/Aim(s)**

- Our objectives are:
- 1. Identify the medical workflow and information needs of battlefield medics and air transport nurses caring for wounded warriors in an operational environment.
  - 2. Develop the platform for hands-free EHR data documentation robust to the environment.
  - 3. Develop natural language processing solution for multi-stage information extraction.
  - 4. Develop systematic assessment instruments based on medical workflow efficacy.

The research targets long-term feasibility of hands-free documentation of injury in operational environments from two fronts: **Medical and Technological**.

- On the medical front:
  - Focus groups/interviews
  - Simulation drills (battlefield, en route, field/hospital care)
- On the technology front:
  - Platform for flexible integration (recording devices, compute devices, end-user)
  - Decoupled recording and processing + parsable performance improvement



Accomplishments: 1. focus groups with EMS personnel, 2. capture & speech recognition system integrated, 3. systematic noise impact study (for speech recognition), 4. two medical drills, 5. medical info extraction from speech

**Goals/Milestones**

**CY17-18 Goals** – Medical Workflow and Platform Development

- Focus Groups, Drill #1
- Platform Integration
- Speech Recognition
- CY18-20 Goals** – Qualitative Assessment and Roadmap Development
- Information Extraction and integration with EHR
- Video Digest
- Drill #1-a-b, #2
- Workflow Assessment

**Comments/Challenges/Issues/Concerns**

- Base system and study to date identifies challenges & promising opportunities for further development of robust solutions.

**Budget Expenditure to Date**

Projected Expenditure: \$1,644,510  
Actual Expenditures: \$1,527,749.91 @ 31AUG2020

**Timeline and Cost**

Activities	17	18	19	20	21
Medical Workflow Studies					
Platform development					
Assessment					
Roadmap development					
<b>Estimated Budget (\$K)</b>			<b>\$893k</b>	<b>\$751k</b>	