

# Technical White Paper

## Overview

End-to-end neural network based approaches to audio modelling are generally outperformed by models trained on high-level data representations. In this paper we present preliminary work that shows the feasibility of training the first layers of a deep convolutional neural network (CNN) model to learn the commonly-used log-scaled mel-spectrogram transformation. Secondly, we demonstrate that upon initializing the first layers of an end-to-end CNN classifier with the learned transformation, convergence and performance on the ESC-50 environmental sound classification dataset are similar to a CNN-based model trained on the highly pre-processed log-scaled mel-spectrogram features.

## Background on Emergency Services

Emergency medical services (EMS)<sup>1</sup> play a crucial role in survival rates throughout the medical sector, resulting in great interest and much effort spent on professionalizing and optimizing each individual EMS. Depicting the global EMS as one is unrealistic due to the multitude of variations in procedures, demographics, and economy. However, there are certain common denominators throughout the emergency care of highly developed countries. Most countries have a centralized 3-digit telephone number, from which an emergency service dispatcher (ESD) answers the phone.

## Responsibilities of the ESD

Throughout an incident, the ESD is first and foremost responsible for diagnosing the severity of the condition. If the diagnosis is wrong, it may result in slower response time and lack of personnel and equipment to stabilize the victim. In most occurrences, the caller is not aware of the victim's condition, which results in a complex investigatory questioning process. In order to ease this process, many ESD's are trained in a medical guideline that considers a triaging system with possible outcomes. This is to provide structure to the conversation and facilitate a faster response time.

### Upon reaching a diagnosis, pre-arrival instructions can help bystanders perform

1 Committee on Trauma, Committee on Shock, Division of Medical Sciences, National Academy of Sciences, National Research Council, USA (1966). Accidental Death and Disability: The Neglected Disease of Modern Society. <https://nap.edu/initiative/committee-on-trauma-and-committee-on-shock>.

life-saving support until first responders arrive at the scene. This has proven to be of utmost importance and is a research field that is continuously receiving more attention<sup>2</sup>.

## The caveats of the ESD

Despite numerous efforts to improve diagnostics and pre-arrival instructions, there still exists a significant variance in survival rates around the world<sup>3</sup>. Amongst the most critical emergencies that an ESD can encounter is the out-of-hospital cardiac arrest (OHCA). From the occurrence of an OHCA until cardiopulmonary resuscitation (CPR) has been initiated, the chance of survival decreases by approximately 7-10% by each passing minute<sup>4</sup>. When a bystander calls the PSAP, one of the first questions posed is whether or not the victim is breathing. Due to various factors, such as agonal respiration, this conclusion is often not clear-cut and results in further questioning before an OHCA is diagnosed. The less ambiguous the conversation is, the faster diagnostics can happen. Upon reaching a diagnosis, the ESD dispatches an ambulance with the necessary personnel and equipment to resuscitate. At this point, the ESD is in charge of disseminating information from the bystander to the ambulance(s), e.g. the victim's location, age, medical histo-

2 Lerner, E.B., Rea, T.D., Bobrow, B.J., Acker, J.E., Berg, R.A., Brooks, S.C., Cone, D.C., Gay, M., Gent, L.M., Mears, G., Nadkarni, V.M., O'Connor, R.E., Potts, J., Sayre, M.R., Swor, R.A., Travers, A.H. (2012). Emergency Medical Service Dispatch Cardiopulmonary Resuscitation Prearrival Instructions to Improve Survival From Out-of-Hospital Cardiac Arrest, A Scientific Statement from the American Heart Association. 125:648-655.

3 Berg, R.A., Tijssen, J.G.P., Koster, R.W. (2010). Global Incidences of Out-of-Hospital Cardiac Arrest and Survival Rates: Systematic Review of 67 Prospective Studies, Resuscitation Journal. 81(11):1479-1487.

4 Larsen, M.P., Eisenberg, M.S., Cummins, R.O., Hallstrom, A.P. (1993). Predicting Survival of Out-of-Hospital Cardiac Arrest: A Graphic Model, Annals of Emergency Medicine. 22(11):1652-8.

ry, and other relevant information, while also instructing the bystander to perform proper CPR. Multitasking in such highly-stressful situations, in which time and precision are of utmost importance, is no small feat.

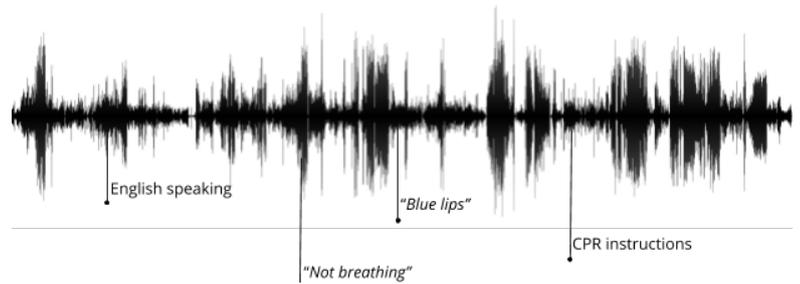
## Live Assistance to Emergency Service Dispatchers

In recent years, we have seen multiple contributions, which utilize machine learning (ML) and artificial intelligence (AI) to significantly outperform human-level performance on tasks considering highly complex data modalities, e.g. natural images and/or audio. These intelligent systems have shown wide usability within fields such as early cancer and tumor prediction<sup>5</sup>. By finding subtle patterns in the data that can correlate and show similarities to previously known samples, these intelligent systems can provide a confidence score for a diagnostic prediction.

During an emergency call, the dissemination of information from a caller to an ESD is reflected in an audio signal. This audio signal contains all vital information needed to perform a diagnosis and thereby decide on appropriate ambulance response and pre-arrival instructions. By letting an intelligent system read the audio signal in real-time, it is possible to provide live assistance to the ESD. The assistance may consist of anything from language/accent detection, keyword detection, appropriate prompts/cues based on the conversation, diagnostic assistance,

pre-arrival instructions, and much more.

The intelligent system is calibrated by learning from a vast amount of historical audio samples. The more conversations the system listens to, the better it gets at assisting the



ESD during calls. This is not only confined to the conversational learnings by a single PSAP but the learnings across all emergency medical services that are utilizing this system.

## Language detection

Corti supports English with several variations (US, England, Australia, etc.) as its primary language, however, in many emergencies calls the caller may not be a native English speaker. For language discordant callers, the ESD's achieve less accurate diagnoses and thereby delayed dispatch<sup>6</sup>. Corti supports accurate detections of 11 of the most spoken languages in the US, including Spanish, Mandarin, Tagalog, and Korean. This enables the ESD to quickly assign the appropriate translator to the call. The number of languages supported by Corti is expected to be well over 100 at the end of 2019.

5 Kourou, K., Exarchos, T. P., Exarchos, K. P., Karamouzis, M. V., Fotiadis, D. I. (2015). Machine learning applications in cancer prognosis and prediction, *Biotechnology Journal*. 13:8-17.

6 Tate, R.C. (2015). The Need for More Prehospital Research on Language Barriers: A Narrative Review, *The Western Journal of Emergency Medicine*. 16(7):1094-1105.

## Conversation cues

Protocols are commonly used by PSAPs globally (estimated 94%<sup>7</sup>) and can be attributed back to the groundbreaking work of Dr. Jeff Clawson. Many studies support the use of a structured questioning process and show strong indications that when ESDs follow protocols strictly, it yields significantly better diagnoses<sup>8</sup>. However, conversations often diverge from the line of questioning, which may leave the ESD with little or no overview of conversation cues.

Corti assists the dispatcher by presenting cues that provide the ESD with insights of the semantics of the conversation. The cues are intelligently prompted to the ESD in a non-invasive manner. This is especially helpful in highly stressful situations, in which the ESD performs a multitude of different tasks, or if the questioning protocol is not followed consistently.

## Pathology detection

Achieving a correct diagnosis is the first step to helping a victim survive, but this can be a difficult task for the ESD. Based on a multitude of studies, there is high variation in detections, which may be due to different criteria for equipping ESDs<sup>9</sup>. However, one point is apparent throughout all studies, and

7 Zachariah, B.S., Pepe, P.E. (1995). The Development of Emergency Medical Dispatch in the USA: a Historical Perspective, *European Journal of Emergency Medicine*. 2:109-112

8 Clawson, J., Olola, C.H.O., Heward, A., Scott, G., Patterson, B. (2007). Accuracy of Emergency Medical Dispatchers' Subjective Ability to Identify when Higher Dispatch Levels are Warranted Over a Medical Priority Dispatch System Automated Protocol's Recommend Coding Based on Paramedic Outcome Data, *Emergency Medical Journal*. 24(8):560-563.

9 Møller, T.P., Andréll, C., Viereck, S., Todorova, L., Friberg, H., Lippert, F.K. (2016). Recognition of Out-of-Hospital Cardiac Arrest by Medical Dispatchers in Emergency Medical Dispatch Centres in Two Countries, *Elsevier Resuscitation*. 109:1-8.

this is the large proportion of misdiagnoses. At the emergency level, this is dependent on the call at hand, and cardiac arrest is considered to be of highest criticality. Corti is equipped with a state-of-the-art cardiac arrest detection system that assists the ESD in detecting one of the most critical calls, both faster and more accurately. By listening in on the call, Corti captures the most subtle features and notifies the ESD if a cardiac arrest should be suspected.

Together with Copenhagen EMS in Denmark and Seattle EMS in USA, Corti has proven to detect cardiac arrest instances that were not detected by ESDs. This has led to an increase in cardiac arrest detection accuracy (recall/sensitivity) by approximately 20% with the average time to detection brought down by approximately 25%. Corti is also resource-efficient, as the solution helps to prevent wrong detections (false positives).

Corti is under constant development, and additional pathology detections are underway with stroke detection in the pipeline for 2018<sup>10</sup>.

## Assisting with pre-arrival instructions

Performing resuscitation and other stabilizing measures in the time before the first responders arrive on the scene of an emergen-

10 Jia, J., Band, R., Abboud, M.E., Pajerowski, W., Guo, M., David, G., Crawford Mechum, C., Messé, S.R., Carr, B.G., Mullen, M.T. (2017). Accuracy of Emergency Medical Services Dispatcher and Crew Diagnosis of Stroke in Clinical Practice, *Frontiers in Neurology*. 8:466.

cy is of utmost importance. Research<sup>11</sup> confirms that bystander CPR has the possibility of increasing the chance of survival four-fold upon encountering an OHCA. However, only one in four bystanders, who are trained in CPR, will initiate CPR without the instruction from an ESD<sup>12</sup>. Thus, pre-arrival instructions by the ESD are crucial. In recent years, the American Heart Association has led a large initiative in achieving recognition of the importance of optimal pre-arrival instructions<sup>13</sup>. Following this initiative, several studies<sup>14,15</sup> have shown that proper pre-arrival CPR instructions can increase survival rates significantly. In collaboration with Seattle EMS in USA, Corti found that more than 47% of the historical cardiac arrest calls, recognized both by the ESD and Corti, lacked adequate CPR instructions. In 8% of the calls, there was no mention of CPR at all. For Copenhagen EMS in Denmark, this number was 16%.

### Upon detection of a pathology, Corti goes

into pre-arrival mode by prompting proper medical guidelines for resuscitation purposes. The purpose of such guidelines is to remind the ESD of the chronology in performing correct CPR.

## Summary

We rely heavily on PSAPs and emergency medical services when we are faced with the worst days of our lives, and we hold ESDs highly responsible for providing swift treatment. However, ESDs work under tremendous pressure and are solely reliant on their own judgment, even in situations in which they, themselves, need advice. By bringing research-based AI into the control room, ESDs can now tap into the collective knowledge from the large source of historical call data, to create better outcomes for future emergencies.

11 Wissenberg, M., Lippert, F.K., Folke, F., Weeke, P., Hansen, C.M., Christensen, E.F., Jans, H., Hansen, P.A., Lang-Jensen, T., Olesen, J.B., Lindhardsen, J., Fosbol, E.L., Nielsen, S.L., Gislason, G.H., Kober, L., Torp-Pedersen, C. (2013). Association of National Initiatives to Improve Cardiac Arrest Management with Rates of Bystander Intervention and Patient Survival after Out-of-Hospital Cardiac Arrest, *JAMA*. 310(13):1377:84.

12 Tanigawa, K., Iwami, T., Nishiyama, C., Nonogi, H., Kawamura, T. (2011). Are Trained Individuals More Likely to Perform Bystander CPR? An Observational Study, *Resuscitation*. 82(5):523-8.

13 Lerner, E.B., Rea, T.D., Bobrow, B.J., Acker, J.E., Berg, R.A., Brooks, S.C., Cone, D.C., Gay, M., Gent, L.M., Mears, G., Nadkarni, V.M., O'Connor, R.E., Potts, J., Sayre, M.R., Swor, R.A., Travers, A.H. (2012). Emergency Medical Service Dispatch Cardiopulmonary Resuscitation Prearrival Instructions to Improve Survival From Out-of-Hospital Cardiac Arrest, A Scientific Statement from the American Heart Association. 125:648-655.

14 Bobrow, B., Panczyk, M., Stolz, U., Sotelo, M., Vadeboncoeur, T., Sutter, J., Langlais, B., Spaite, D. (2014). Statewide Implementation of a Standardized Prearrival Telephone CPR Program is Associated with Increased Bystander CPR and Survival from Out-of-Hospital Cardiac Arrest, *Circulation*. 130:A1.

15 Song, K.J., Shin, S.D., Park, C.B., Kim, J.Y., Kim, D.K., Kim, C.H., Ha, S.Y., Eng Hock Ong, M., Bobrow, B.J., McNally, B. (2014). Dispatcher-Assisted Bystander Cardiopulmonary Resuscitation in a Metropolitan City: a Before-After Population Study, *Resuscitation*. 85(1):34-41.