# DeepCARS Project

## Main Project III

2018-2020

# DeepCARS Project Summary

- After graduate school, at my previous employer, I developed early prediction and classification models for cardiology patients, capable of predicting events such as cardiac arrest.
- We called this project DeepCARS which calculates the likelihood of cardiac arrest by utilizing five vital signs (HR;heart rate, RR; respiratory rate, SBP; systolic blood pressure, DBP; diastolic blood pressure, and BT; body temperature).
- Here, I contributed to building from the initial stage of the project to technological development. In particular, I developed the basic analysis framework to predict the cardiac arrest risk within 24 hours to give early notification for professionals in hospitals to take precise decisions.
- It was a real-world issue very different from development environments and our team created missing data imputation methods, batch sampling for data imbalances, dataset construction, and architecture designs to create a robust, real-world framework.
- Our team successfully created a prototype that is being tested in Korean hospitals. Our prototype is capable of predicting cardiac arrest in advance and saving patients' lives.
- This project was mainly implemented in Python and Tensorflow 1 & 2.
- Through this experience, I came to understand the necessity of robustness when applying engineering concepts to the real world.

# DeepCARS Project : Part Member Summary

- **Contribution**
  - Develop deteriorating patient early prediction/classification model
    - Study design, data processing, architecture design, and evaluation in tabular data domain
- **Development**
  - Python, Tensorflow 1, 2
- **Issues**
  - Raw data preprocessing (data cleansing)
  - Data imbalance & feature engineering (batch sampling, feature quantization, validation set)
  - Sequential architecture design (LSTM & Transformer, ensemble, and so on)
- **Achievement**
  - Create a prototype to provide Korean hospitals
  - Our prototype can predict cardiac arrest in advance and save patients' lives
  - Four papers in clinical journals (Details in Publications, co-first three papers)

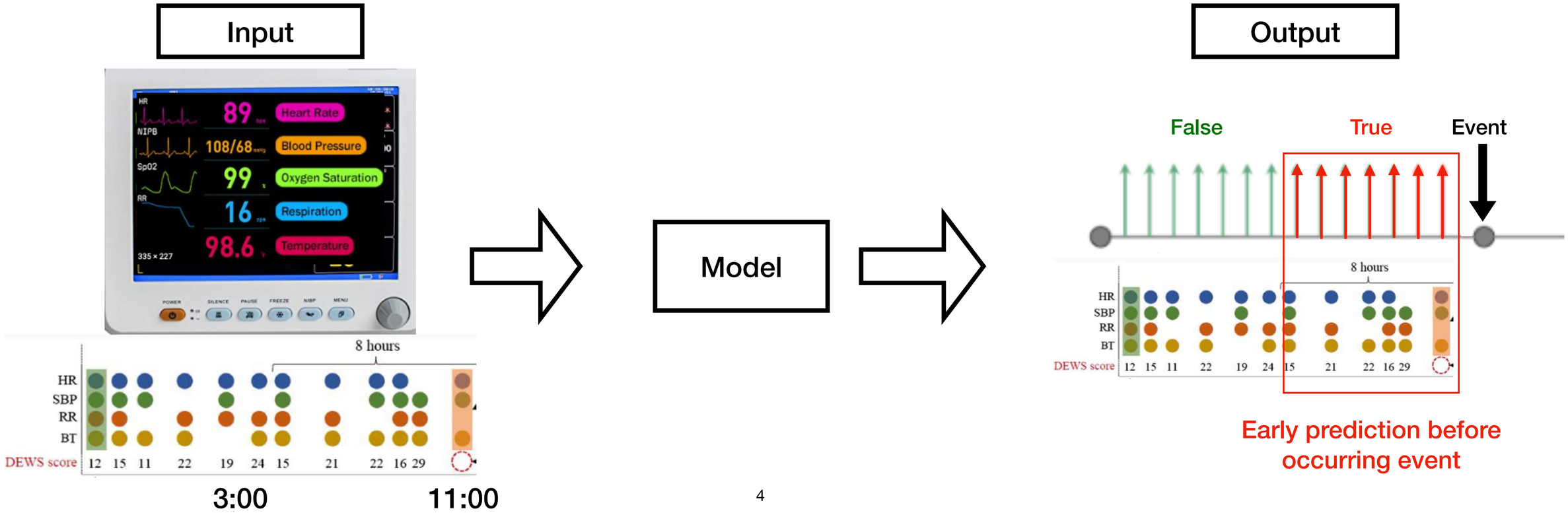
# DeepCARS Project Introduction

## Input & Output definition

- Input: Discrete time-series data (5 vital signs; HR, SBP, DBP, RR, BT)
- Output: Deteriorating heart diseases (cardiac arrest, mortality, and so on) predict/classify

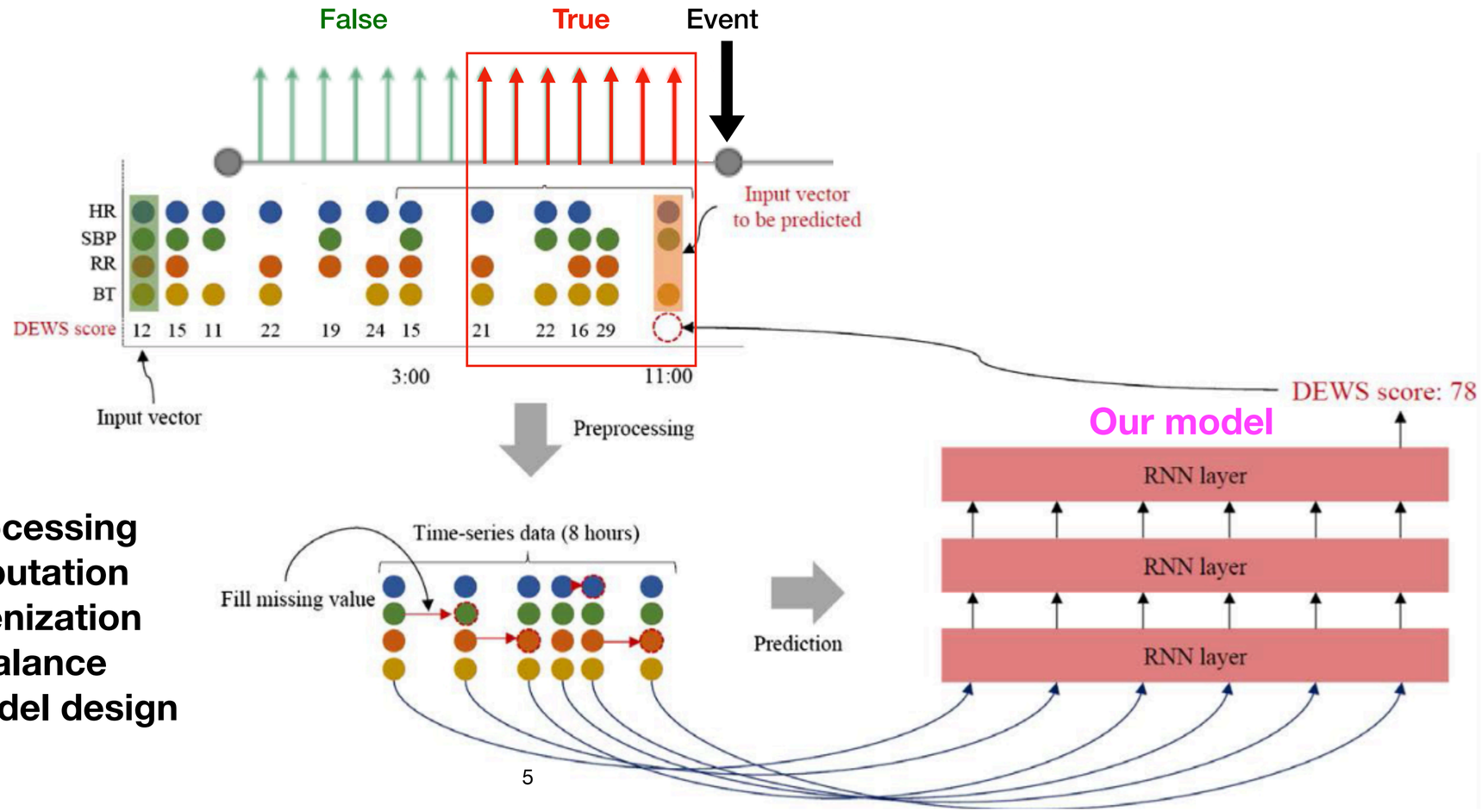
## Motivation

- Developing an intelligent AI-based medical solution based on EMR data



# DeepCARS Project
# Project overview

- Problem Definition
  - Predicting deteriorating events within N hours prior to events

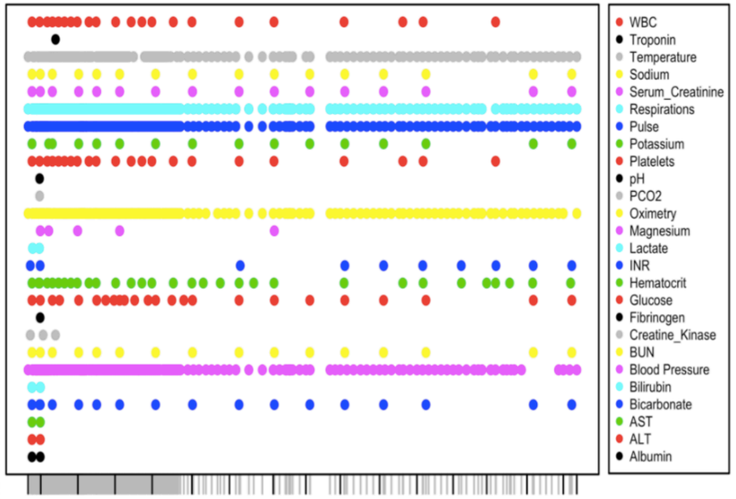


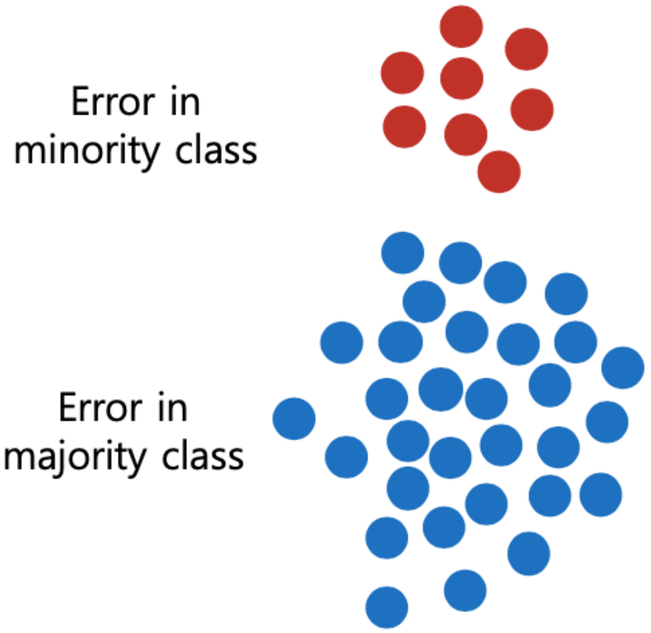

1. **Input preprocessing**
2. **Missing imputation**
3. **Feature tokenization**
4. **Class Imbalance**
5. **Sequential Model design**

# DeepCARS Project
# Project Issues

- Preprocessing
  - Unstructured and uncleaned raw data
- Missing values
  - Need to fill out missing values
- Class imbalance
  - Unbalance class ratio

| ADMTIME | RECTIME | RR | BT | SBP | AVPU |
|---|---|---|---|---|---|
| 20180711 | 0180709 10:3 | 36.7 | 36.1 | 120 | A |
| 20180711 | 0180709 18:3 | 36.2 | 36.2 | 121 | Alert |
| 20180711 | 0180709 22:4 | 18 | 36.3 | 122 | A |
| 20180711 | 0180710 07:2 | 15 | 36.4 | 120 | A |
| 20180711 | 0180710 13:0 | 17 | 36.5 | 119 | A |
| 20180711 | 0180710 21:0 | 15 | 36.6 | 130 | A |
| 20180711 | 0180711 10:3 | 18 | 36.7 | 133/121 | A |
| 20180711 | 0180711 18:3 | 15 | 36.8 | 122/121 | A |
| 20180711 | 0180711 22:4 | 17 | 36.3 | 122 | A |
| 20180711 | 0180712 07:2 | 15 | 36.4 | 120 | Alert |
| 20180711 | 0180712 13:0 | 18 | low | 119 | - |
| 20180711 | 0180712 21:0 | 15 | Low | 133 | - |




- Feature tokenization (see above preprocessing input)
  - Raw data should change to other form (e.g., from scale value to feature vectors) for training

# DeepCARS Project Contribution

- Input pre-processing
  - Raw data cleansing (basic code implementation)
- Missing imputation
  - Filling out the missing information (e.g., Forward Filling), Missing imputation considering input relationships
- Feature tokenization
  - Transforming vital signs (scale value) into embedding vectors  (missing data information, time-delta, …)
- Class imbalance
  - Over or under sampling approach dealing with low positive cases (cardiac arrest)
- Model design
  - Sequential architecture (LSTM DenseNet) design

# DeepCARS Project Results

- Through the results of a multicenter retrospective clinical trial (173,368 patients), the accuracy of predicting cardiac arrest within 24 hours (AUROC) was 0.860 in the internal cohort and 0.905 in the external cohort, demonstrating high accuracy in various clinical environments.

- The average time from the first predicted time of the cardiac arrest to the actual occurrence is 15.8 hours, which helps the efficient operation of medical resources by providing information on the prediction of cardiac arrest within the time required for medical staff to take sufficient preventive measures.

  - **[Ministry of Food and Drug Safety Clinical Trial Results (VN-M-05) in Asan Hospital, *Retrospective case-control study]**

# DeepCARS Project Conclusion

- Most approaches are new and novel, and effectively combined in an entire framework
- Through this project, I published several papers as a co-first author, and this was my first research to apply technology to the real-world environment.
- I came to learn how to build up a robust model setup and understand performance (reducing false-positive alarms and improving high true-negative cases)

## Detecting Patient Deterioration Using Artificial Intelligence in a Rapid Response System

Kyung-Jae Cho, MS[1]; Oyeon Kwon, MS[1]; Joon-myoung Kwon, MD, MS[2]; Yeha Lee, PhD[1]; Hyunho Park, MD[1]; Ki-Hyun Jeon, MD, MS[3]; Kyung-Hee Kim, MD, PhD[3]; Jinsik Park, MD, PhD[3]; Byung-Hee Oh, MD PhD[3]

**Objectives:** As the performance of a conventional track and trigger system in a rapid response system has been unsatisfactory, we developed and implemented an artificial intelligence for predicting in-hospital cardiac arrest, denoted the deep learning-based early warning system. The purpose of this study was to compare the performance of an artificial intelligence-based early warning system with that of conventional methods in a real hospital situation.
**Design:** Retrospective cohort study.
**Setting:** This study was conducted at a hospital in which deep learning-based early warning system was implemented.
**Patients:** We reviewed the records of adult patients who were admitted to the general ward of our hospital from April 2018 to March 2019.
warning system had up to 257% higher sensitivity than conventional methods.
**Conclusions:** The developed artificial intelligence based on deep-learning, deep learning-based early warning system, accurately predicted deterioration of patients in a general ward and outperformed conventional methods. This study showed the potential and effectiveness of artificial intelligence in an rapid response system, which can be applied together with electronic health records. This will be a useful method to identify patients with deterioration and help with precise decision-making in daily practice. (*Crit Care Med* 2020; 48:e285–e289)
**Key Words:** artificial intelligence; cardiology; critical care; deep learning

Critical Care Medicine, IF:7.447

30 citations (on 2022.11.14), co-first author

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Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

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Clinical paper

## A multicentre validation study of the deep earning-based early warning score for predicting in-hospital cardiac arrest in patients admitted to general wards

*Yeon Joo Lee[a,1], Kyung-Jae Cho[b,1], Oyeon Kwon[b], Hyunho Park[b], Yeha Lee[b], Joon-Myoung Kwon[c], Jinsik Park[d], Jung Soo Kim[e], Man-Jong Lee[e], Ah Jin Kim[e], Ryoung-Eun Ko[f], Kyeongman Jeon[f,g], You Hwan Jo[h,i,*]*

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[b] *VUNO, Seoul, Republic of Korea*
[c] *Department of Critical Care and Emergency Medicine, Mediplex Sejong Hospital, Incheon, Republic of Korea*

Resuscitation

4 citations (on 2022.11.14), 2nd author