Personalized Physician Recommendation for Critical Care Using the TreeSHAP Method

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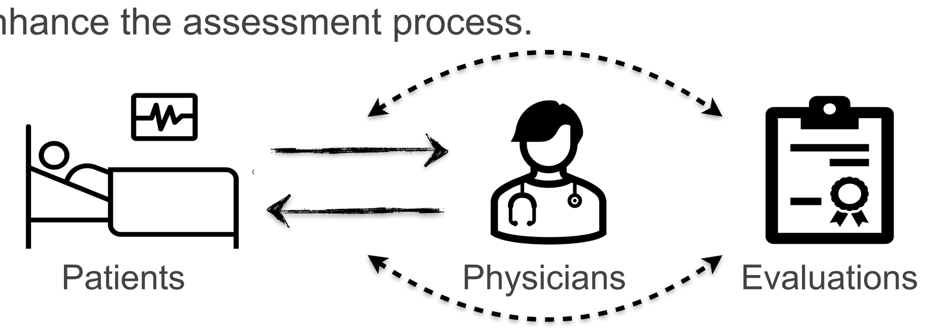
Introduction

❖ **Background:**

- The physician performance is critical to taking care of patients admitted to the ICU who are in life-threatening situations and require high level medical care and interventions.
- Quality assessment is beneficial to ensuring high standard medical care, which also stimulates performance improvement for physicians.
- Traditionally, 360 evaluations are used to assess the quality of physician performance via questions linked to 7 domains, including communication, management, professionalism, and others, which, however, fail to accommodate individual characteristics for both physicians and patients.

❖ **Objectives**:

- Define sensible measures to reflect patient-specific outcomes.
- Examine whether patient outcomes differ in ICU department.
- Determine whether physician 360 evaluations explain any observed differences in patient outcomes.
- Construct a physician-ranking scheme for newly admitted patients in ICU, where the quality of physician performance is reflected in terms of improved predicted patient outcomes. Such ranking offers a personalized recommendation and serves as a complement to the traditional physician 360 evaluations to enhance the assessment process.



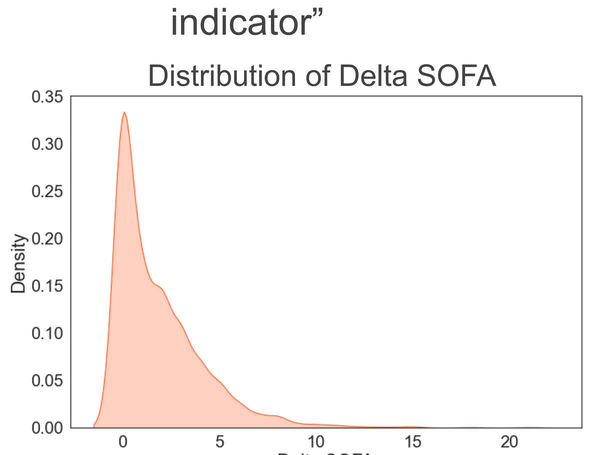
❖ **Data**:

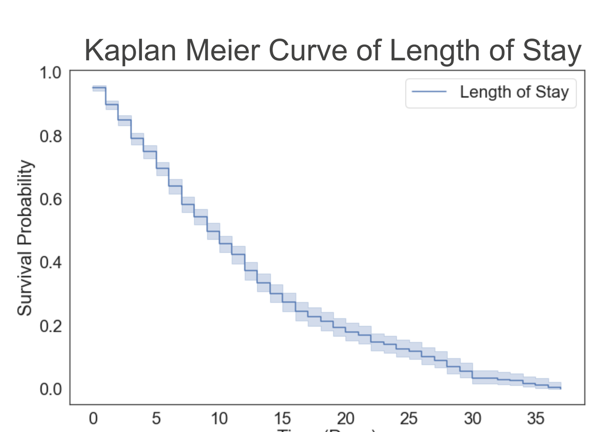
- The ICU data set contains information about 2113 patients and 25 physicians:
  - Characteristics for both patients and physicians
  - SOFA trajectories for patients
  - 360 evaluations for physicians

Definition of Quality

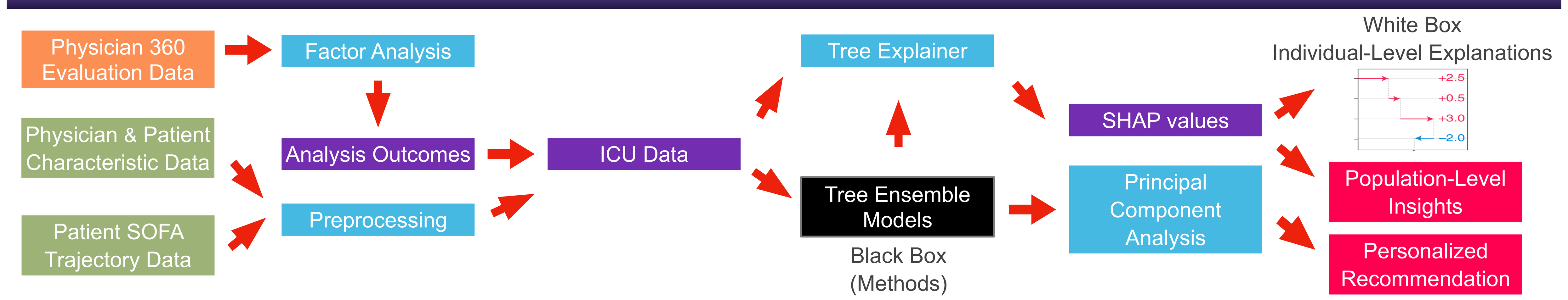
❖ **3 Measures for Patient Outcomes**:

- Y_1 : Delta SOFA
  - Y_1: Max SOFA value minus the SOFA value at ICU admission
  - Delta SOFA has been shown to be a valid tool for assessing the morbidity in critical illness.
- Y_2 : Discharge Status
  - $Y_2 = I$(Patient is dead at ICU discharge)
  - 1125 (53.24%) patients were discharged from ICU
  - 988 (46.76%) patients died in hospital
- Y_3 : ICU Length of Stay
  - Y_3 with Y_2: viewed as "survival time" with "censoring indicator"





Statistical Methods



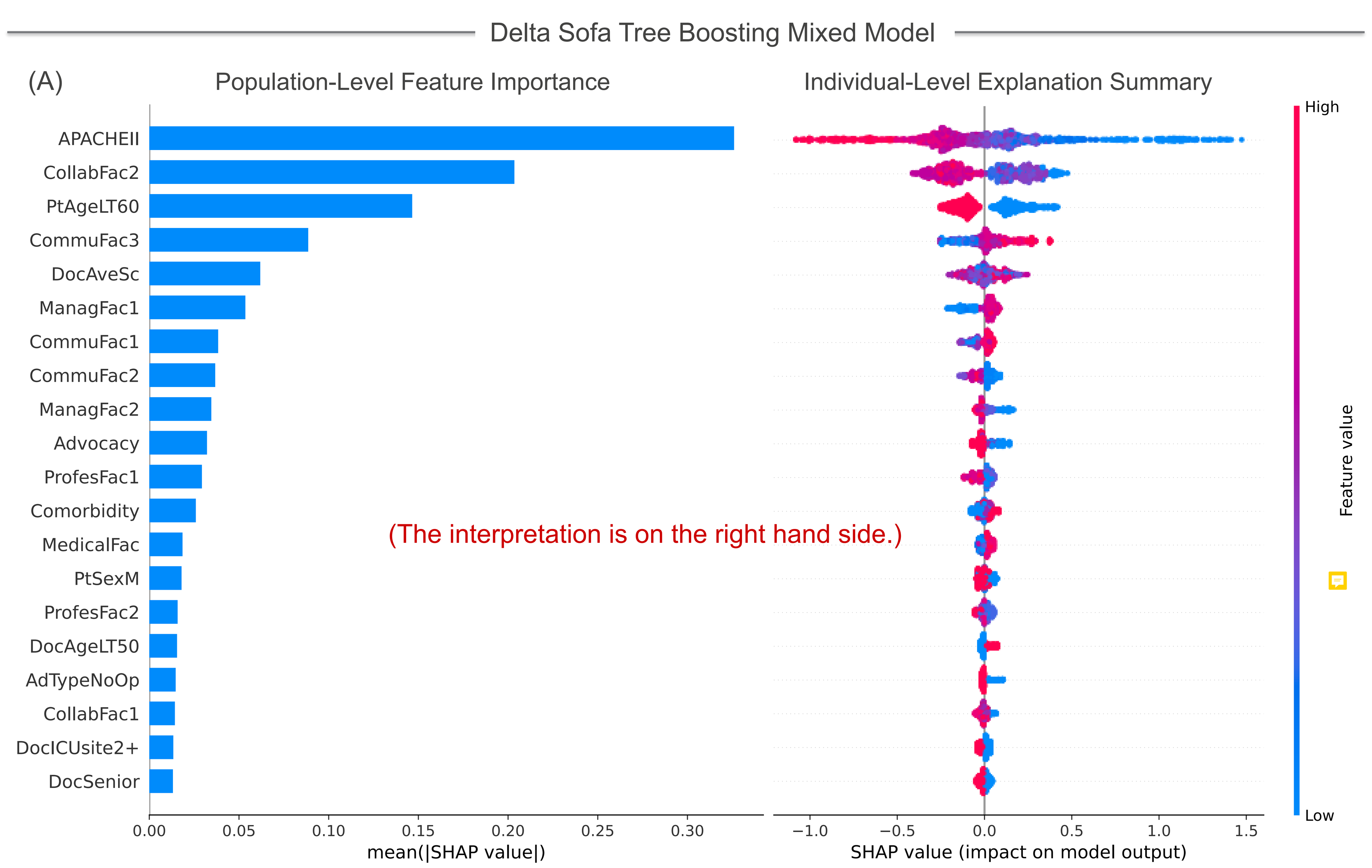
❖ **Tree Ensemble Models:**

- Y_1 : ♦ XGBoost ♦ Random Forest ♦ Tree Boosting Mixed Model (grouped by the ICU department)
- Y_2 : ♦ XGBoost ♦ Random Forest ♦ Tree Boosting Mixed Model (grouped by the ICU department)
- Y_3 & Y_2 : ♦ Cox Model with XGBoost ♦ Accelerated Failure Time Model with XGBoost

❖ **TreeSHAP Method:**

- The Tree SHapley Additive exPlanations (TreeSHAP) method is an effective approach to compute optimal Shapley values for tree based models to explain interaction effects, individual-level predictions, and population-level feature importance.

Visualization of Results

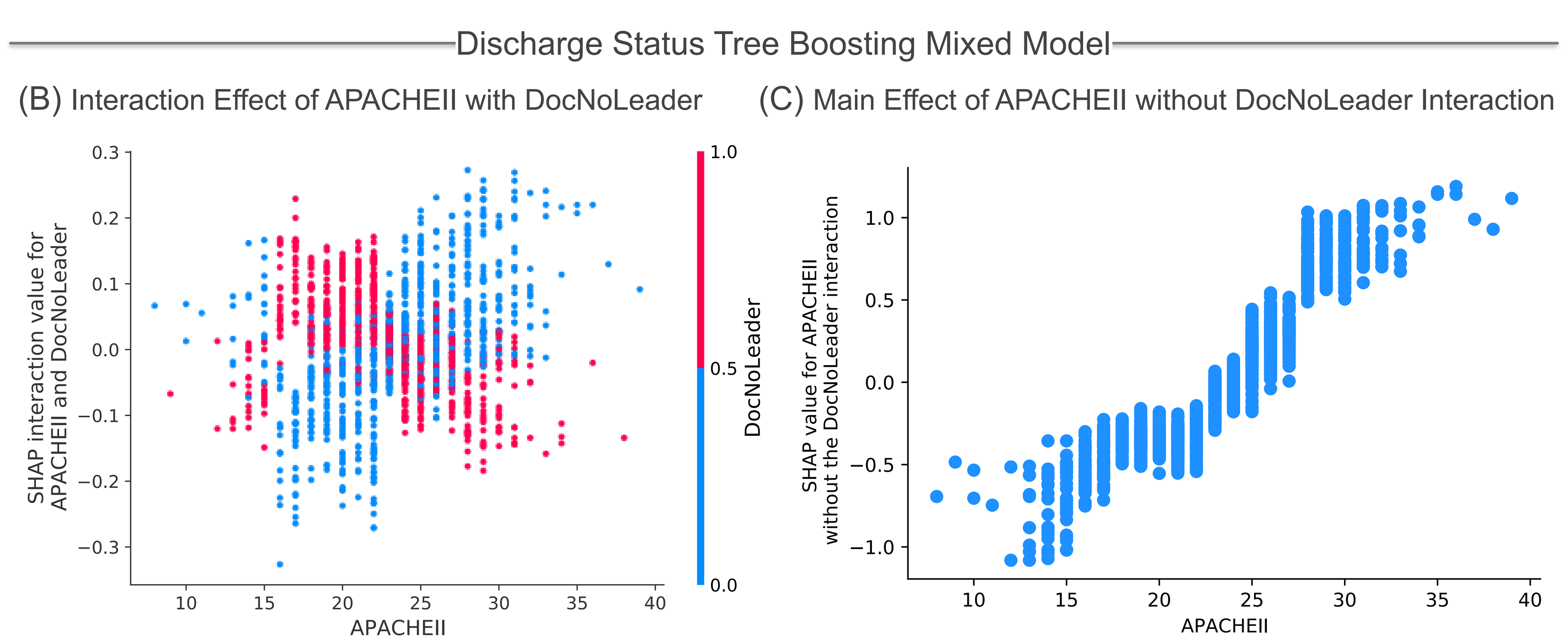


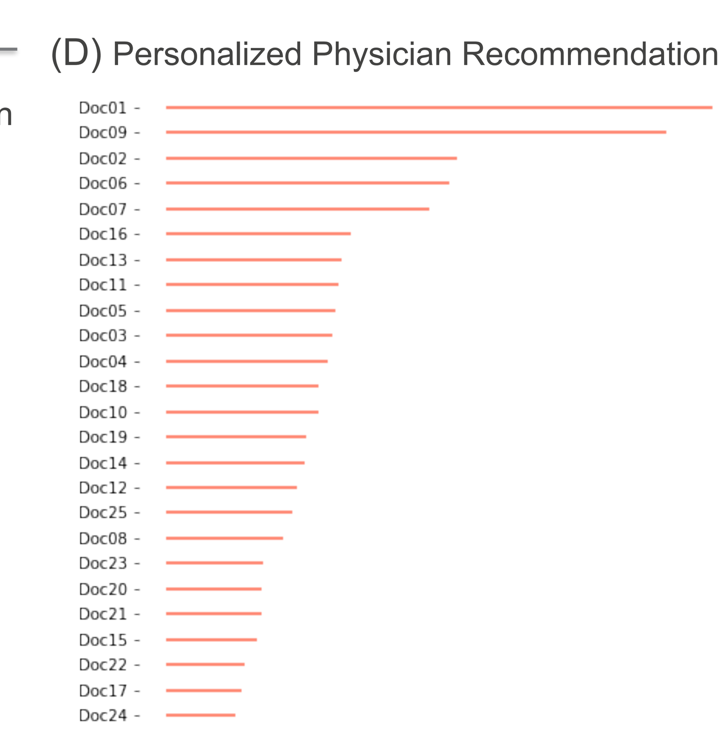
(A) Bar chart (left) for the average SHAP value magnitude and a set of beeswarm plots (right): each dot corresponds to an individual patient in the study. The dot's position on the x axis shows the impact that variable has on the model's prediction for that patient. When multiple dots land at the same x position, they pile up to show the density.

(B) shows how the effect of APACHEII on patient mortality varies with the physician leadership role.

(C) delineates the main effect of APACHEII on patient mortality without the interaction with the physician leadership role.

(D) Plot of the personalized physician recommendation index for a randomly created new patient.

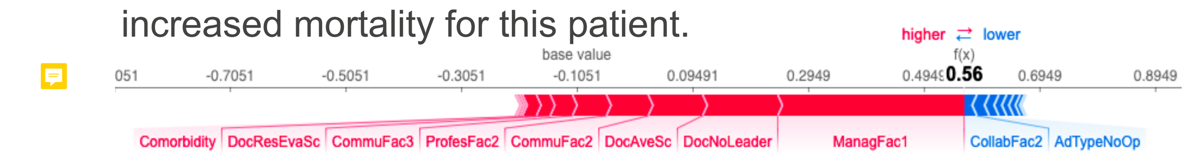




Conclusion & Discussion

❖ **Summary of Findings**

- For all the patient outcomes and the corresponding tree ensemble models we considered,
  - APACHEII, a score reflecting the condition of the patients at ICU admission, is the most important variable for explaining the difference in patient outcomes.
  - Other important factors of physician 360 evaluations for explaining the patient outcomes include CollabFac2, CommuFac2, CommuFac3, ManagFac1, MedicalFac, and ProfesFac1. But the importance level of those factors can be revealed differently, depending on what specific measure is used for the patient outcome and the tree ensemble models.
  - The difference in ICU departments does not contribute to improve the patient outcomes significantly.
- Using the TreeSHAP method, we can also visualize the variable attribution for each patient. For example, the following plot shows that for the patient with ID 101008, the predicted fixed effect of the probability of death at discharge is 0.56, with the baseline value being -0.11. Certain physician 360 evaluation factors, such as ManagFac1 and CommuFac2, are associated with the increased mortality for this patient.



- To offer personalized physician recommendation for each new patient admitted to the ICU, we take the well-trained tree ensemble models and input the patient's characteristics together with the physician characteristics and 360 evaluations. This is implemented based on a tier list of a comprehensive index using the weighted sum of the principal components of predicted Delta SOFA, discharge mortality, and ICU length of stay for all physicians working in the ICU. This procedure is a more adaptive and effective way of assigning physicians for patients than the current practice.

❖ **Strength and Limitation**

- Strength
  - Tree ensemble models automatically incorporate the non-linearities and interactions of the variables; they often outperform other machine learning models in many applications.
  - The TreeSHAP method provides a fast and precise computation of Shapley values to explain the tree ensemble models.
  - Using mixed effects models to account for heterogeneity among patients allows for the uncertainty quantification and efficient learning of the fixed effect.
- Limitation
  - As incomplete observations are present in the data, our analyses here are conducted under the assumption of missing completely at random (MCAR) mechanism.

Code Availability

Code supporting this study is published online at https://github.com/y-bian/pprccutm. (For now, it's still private and empty)

Selected Reference

Lundberg, S. et al. (2020). From local explanations to global understanding with explainable AI for trees. *Nature Machine Intelligence*, 2(1), 56-67.

Acknowledgement

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