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Causal Inference in the Multiverse of Hazard

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Abstract

Hazard is an important estimand in both application and methodology. However, the issue regarding its causal interpretation has also been recognized, such as the built-in selection bias and an ill-defined population to be compared between different treatment groups. Here we propose a new definition of hazard under a counterfactual framework. Instead of *conditioning* on the prior survival status as a conditional probability, the new definition is a marginal probability *intervening* in the prior status. We illustrate by the single world intervention graphs that the proposed counterfactual hazard is a type of controlled direct effect, the effect not through the prior outcomes and that the treatment-outcome and outcome-outcome confounders need to be adjusted to ensure its identifiability. Conceptually, the intervention in the survival status at each time point creates a new counterfactual world such that the proposed hazards across different time points represent a collection of risks in the created counterfactual worlds, i.e., the multiverse. The sum and average of the risks across the multiverse are the cumulative and average counterfactual hazard, respectively. We further show that the actual risk in our observed world lies between the two. The conceptual breakthrough is that we reformulate the hazards in the actual world as a collection of risks in the counterfactual worlds. This is a joint work with Dr. En-Yu (June) Lai (Institute of Statistical Science, Academia Sinica).

Keywords:
Causal Inference; Counterfactual Process; Hazard; Multiverse; Survival Analysis.