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HELPING ACUTE-CARE HOSPITALS RUN MORE SMOOTHLY USING SIMULATION AND CENSUS DATA ANALYSIS

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ABSTRACT

We present a data-driven approach for classifying heterogeneous clinical units in full-scale acute-care hospitals and corresponding strategies for simulating patient census based on the clustering profiles. This approach provides an entry point for understanding the patient flow in big hospitals and serves as the basis for down-stream analysis such as strategic personnel planning and tactical nurse scheduling. Based on weekly historical patient census patterns, we classify departments into four categories in reference to intra-week and inter-week variations. Two non-parametric Monte Carlo simulation strategies are proposed to target departments with different profiles. For validation, we use the data from a hospital system with a dozen facilities, and show that the clustering is clinically relevant and the simulation retains key features of the real data.

1 INTRODUCTION

Philips Healthcare Transformation Services, the consulting arm of Royal Philips, is contracted by a large hospital system to provide workforce optimization solutions for its facilities. In total, there are about 200 clinical units of various types, including emergency, intensive care, pediatrics and cardiovascular care from a dozen facilities. For each unit, we have hourly patient census data (a snapshot of the number of patients in the unit at that time) that span more than two years. We convert the hourly sequence into weekly chunks (the choice of a week as the unit of time is specific to this project, but other time unit options, such as day and month, could also be used). Some of the units have a consistent pattern within the weekly chunks (daily ebbs and flows), and some of the units have large variations across the weeks (busy and light weeks).

2 CLUSTERING OF HOSPITAL UNITS

A key novelty of our framework is that all hospital units can be handled in an integrated fashion. Motivated by analysis of variance from the classical statistics literature, we define two metrics that capture two main sources of variation in patient census: intra-week variation and inter-week variation. Therefore, all units naturally fall into four patterns (See Fig.1). This is a crucial step in handling the heterogeneous hospital units all at the same time, rather than to develop a simulation model for each unit one at a time.

3 SIMULATION STRATEGIES

We developed targeted simulation strategies for the two patterns we identified, namely *sequential turning points sampling* and *conditional random walk sampling*. The sequential turning points sampling algorithm takes advantage of the fact that the low inter-week and high intra-week variation units have consistent turning points (the hour at which the trend of patient census reverses). The Conditional Random Walk Sampling is

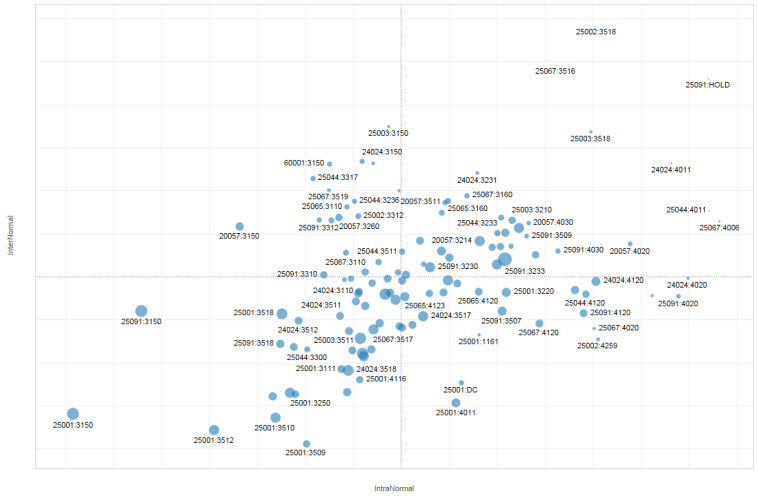

Figure 1: Clustering of hospital units based on intra- and inter-week variations.

inspired by the observation that a lot of other units have a stable-jump-stable-jump type succession present in patient visits. The two simulation strategies are essentially non-parametric, in the sense that they are not governed by any parametric form and can adapt to the data in a flexible way.

4 VALIDATION

After some tweaking of the meta-parameters, such as the length of windows for conditional random walk sampling, we can generate a simulated patient census that mimics the real data and retains key features (such as the daily fluctuating pattern). Fig.2 compares the simulated patient census with the real patient census for two units based on Sequential Turning Points Sampling (left) and Conditional Random Walk Sampling (right).

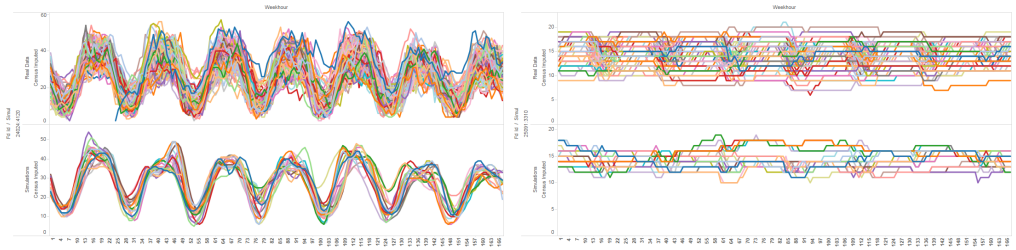

Figure 2: Simulated patient census (lower) as compared with the real data (upper). Patient census curves for different weeks are overlaid. Left: sequential turning points sampling; Right: conditional random walk sampling.

5 CONCLUSION

The use of pre-simulation clustering enables us to handle the units in a hospital holistically, rather than getting results in a siloed manner. This enables further down-stream integration, such as floating-pool nurses sharing. The two non-parametric simulation strategies are robust and targeted, and seem to work well in replicating the patient census data.